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Abstract

The Natural History Museum in Vienna is well known for its extensive collection of skeletonized elements of various origins. However, some time ago, mummified remains were discovered in a special side cabinet that had not yet been scientifically examined. This involves mummies from unknown regions as well as from Egypt, Peru and the New Hebrides archipelago.

In the following thesis, nine preserved mummified heads, as well as 15 skulls that have already been completely skeletonized but are listed in the inventory book as mummy skulls, were examined. The aim of this work was to find answers to a wide variety of questions regarding these 24 case studies: Where do these mummy remains come from, how old are they, who collected each of them, which traces of their lifeways can be reconstructed, which taphonomic processes help to understand what secrets are hidden under the wrapped faces or in the fact that some of them were skeletonized? To answer these questions, various methods, such as X-rays and micro-computed tomographic imaging, as well as ^{14}C dating were employed.

Using these methods, 12 skulls could be assigned to the Egyptian origin (seven of them are mummified heads) and 11 skulls to the Peruvian origin (one of them is mummified). Only one mummified skull could be attributed to the New Hebrides archipelago. Six out of a total of 24 skulls could be classified to the female sex, 15 to the male sex and two were considered as indifferent. The age groups range from "child" to "old adult", with "middle adult" being the most common age group with a total of 12 individuals. For the remaining individuals, one can be categorized as "child", three as "adolescent", six as "young adult" and two as "old adult". With the help of international scientific cooperation, valuable information was exchanged and uncertainties regarding pathological and taphonomic findings were clarified. These findings and many other investigations resulted in a palaeopathological report complemented by archaeological findings without destroying the embalming material and the soft tissue. In summary, among the 24 cases of (earlier) mummified heads analyzed herein, for four of them, all multi-method variables could be adequately described and contextualized.

Results showed that comparing the findings with literature, a much better contextualization could be attained for most of the 24 case studies, providing scientific value for more in-depth studies, not only of those mummies analyzed herein, but for mummy studies in general.

Zusammenfassung

Das Naturhistorische Museum in Wien ist bekannt für seine umfangreichen Bestände von Skelettsammlungen verschiedenster Herkunft. Dazu zählen auch einige seltene Mumienteile, die bis zu diesem Zeitpunkt noch keiner wissenschaftlichen Untersuchung unterzogen wurden. Dabei handelt es sich um Mumienteile aus den Regionen Ägypten, Peru und der Inselgruppe Neue Hebriden.

In dieser Arbeit wurden neun konservierte bzw. mumifizierte Schädel, sowie 15 Schädel, die bereits vollständig skelettiert sind, im Inventarbuch jedoch als Mumien Schädel angeführt sind, untersucht. Das Ziel dieser Arbeit war es, Antworten auf die unterschiedlichsten Fragestellungen zu bekommen: Woher stammen diese Mumienreste, wie alt sind diese und welche Geheimnisse verstecken sich in den eingepackten Gesichtern? Um diese Fragen zu beantworten, wurden verschiedene Methoden, darunter bildgebende Verfahren, angewandt. Dazu zählen radiologische Untersuchungen wie Röntgen und mikro-computertomographische Bildgebung, sowie ¹⁴C-Datierungen, welche Hinweise auf das Fundalter der Mumien gaben.

Anhand dieser Methoden wurden 12 Schädel der Herkunft Ägypten (sieben davon sind mumifizierte Köpfe) und 11 Schädel der Herkunft Peru (wovon einer mumifiziert ist) zugeordnet. Ein einziger mumifizierter Schädel wurde der Inselgruppe Neue Hebriden zugeschrieben. Von den insgesamt 25 Schädeln konnten sechs dem weiblichen Geschlecht, 15 dem männlichen Geschlecht und zwei als indifferent zugeordnet werden. Bei den Altersgruppen sind von „Kind“ bis „älterer Erwachsener“ alle Altersgruppen vortreten, wobei die „mittleren Erwachsenen“ mit 12 Individuen, die häufigste Altersklasse darstellen. Bei den restlichen Individuen kann eines als „Kind“, drei als „Adoleszent“, sechs als „junge Erwachsene“ und zwei als „ältere Erwachsene“ kategorisiert werden. Mit Hilfe internationaler wissenschaftlicher Zusammenarbeit konnten wertvolle Informationen ausgetauscht und Unsicherheiten bezüglich pathologischer und taphonomischer Befunde geklärt werden. Das ermöglichte die Erstellung eines paläopathologischen Berichtes, der durch archäologische Befunde ergänzt wurde, ohne das Einbalsamierungsmaterial und das Weichgewebe zu zerstören. Zusammenfassend lässt sich sagen, dass von den 24 Fällen der (früher) mumifizierten

Köpfe, die in diese Arbeit analysiert wurden, bei vier von ihnen alle multimethodologischen Variablen angemessen beschrieben und kontextualisiert werden konnten.

Die Ergebnisse zeigten, dass durch den Vergleich der Befundung mit Literaturangaben eine viel bessere Kontextualisierung für die meisten der 24 Fallstudien erreicht werden konnte, was einen wissenschaftlichen Wert für tiefer gehende Studien bietet, dies gilt nicht nur für die hier analysierten Mumien, sondern für Mumienstudien im Allgemeinen.

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1 Introduction

1.1 Mummification: Why, wherefore, how come?

Everyone has heard about mummies at some point or another. For example, one of the most famous and well-known mummies is that of King Tutankhamun. He plays a main role in a number of fantasy films and books, for both children and adults, but also in documentaries. There are even video games with mummies as main character. But how much is really known about the origin of mummies and the mummification processes? With the help of the always improving technology it is possible to get an increasingly better insight into the history of mummies.

As a result, it is possible to extract a great amount of information from the mummies, for example by means of computer tomography or X-rays, without having to unpack or destroy the mummified parts.

But of what mummy remains are we talking here at all? A few years ago, barely inventoried mummy remains were discovered in a nailed-up cupboard in the Department of Anthropology of the Natural History Museum of Vienna. They ranged from loose mummified extremities to embalmed animals and impressive mummy skulls. For a total of 11 of these mummified remains, no evidence of inventory could be found. Due to the fact, that for many of these mummy parts no or very little information has been available so far, I was able to take the opportunity to find out some of the history of these mummies using non-invasive methods.

1.2 Aims of this work

The general aim of this work was to produce comprehensive reports on 24 case studies of mummified human heads recently found in the Department of Anthropology of the Natural History Museum in Vienna. As many of them were either poorly or not at all described or mentioned in the Department's inventory book, the main aim herein was to reconstruct either their more specific provenance history or to assign them at least to a

specific country of origin. Attempts to define chronological horizons for each of the cases were also aimed for.

To reach these objectives provenance research was carried out on the archival documentation of the Department on each of the cases, as well as multi-method analyses on the human remains themselves. It must be stressed that provenance research was not exhaustive, that is, no attempt was made herein to reconstruct the exact way these remains have been obtained from their original resting places. Age at death and sex estimation, dental health, examination for intentional cranial modification, trauma and injuries, as well as selected palaeopathological and taphonomical changes and features of the embalming techniques were used to differentiate between the cases. The methods used herein include macroscopic and endoscopic observation, X-ray and micro-CT imaging, 3-D scanning and 3-D print.

1.3 Disclaimer and Ethical Aspects

Please note: This work includes images of mummies and skeletonized human remains.

The subject of the following work are human remains from different time periods and different countries. Consequently, they are extensively described and discussed. These human remains were always treated with dignity and respect regardless of age or provenance. However, these descriptions and figures may trigger unwanted emotional responses.

Furthermore, to the best of knowledge and belief, consideration was taken not to work with illegally acquired cultural objects or human remains. However, as the exact provenance was not previously known, no attempts were made herein to contact eventual communities of origin and discuss ethical boundaries. Due to the fact, that in some cases there was still mummified soft tissue, hair etc. attached to the bones, it was ensured that the biological remains were curated in adequate environmental standards to ensure their long-term survival. Samples were also taken in a few cases. In this context, special care was taken to ensure that the invasive methods used for this study would not interfere with future investigations.

1.4 Short overview on mummies

For better understanding about mummies, Lynnerup (2007) gives a definition. He describes mummies as human or animal remains with preservation of nonbony tissues. There has to be intact skin and/or some preserved internal organ structures on body parts or the whole body. In some cases, one can distinguish muscle fasciae, ligaments and even tissues of internal organs and muscles. But more often soft tissues are very hard to identify because the organs are shrunken and desiccated due to the process of decomposition and dehydration. Furthermore, in many instances internal organs are completely removed. In most cases, tissues with a high content of collagen are well preserved. This includes the dermis, muscle fasciae and tendons.

Many parameters play an important role in the state of conservation of mummies (Lynnerup, 2007). The preservation of mummies depends on mortuary practices, the environmental parameters and the time span since death. Two types of mummification can be distinguished in general: natural mummification and artificial mummification. Natural mummification can be caused by extreme heat or cold for most of the year, or by anaerobic tomb environment, salty or alkaline soil conditions, or preservation by highly absorbent substances in direct contact with the cadaver (such as sand). In contrast, there is artificial mummification where evisceration of internal organs and soft tissues or replacement of soft tissue with other materials such as clay, stuffing of the body with grass, sticks or other reinforcing elements may occur. Desiccation in this type of mummification can also be achieved by controlled fire and smoke and in some cases bitumen, balsam or other resinous substances are used to desiccate the dead body (Cockburn et al., 1998).

All the examined mummified remains from the Natural History Museum could be assigned to three regions of origin: Egypt, Peru and Melanesia. In order to be able to assign these mummy parts to a time period, the following chapters describe the different techniques of mummification in Egypt, Peru and Melanesia, subdivided according to temporal changes.

The Egyptian timeline is divided in different dynasties. There is abundant literature with numerous time references concerning the dynasties. Originally, Egyptian dynasties were derived from the length of the reigns. With the help of measurements of the radiocarbon activity of archaeological findings as well as historical information on the lengths of the dominions, the various dynasties can be represented very well in a restricted time frame. The most ancient artificial mummies produced in Egypt can be assigned to the Predynastic Period (4350 – 3075 BC) and the Early Dynastic Period (3075 – 2875 BC) (Dee et al., 2013). Each period is subdivided in different dynasties, characterized by rulers with similar ancestry. From dynasty to dynasty the preservation gets increasingly better and at New Kingdom times (1539 – 1077 BC) the mummification process achieved a very high degree of preservation which includes an almost complete desiccation process of many days and the usage of many different materials. Not every person buried received elaborate mummification processes. These often complex methods were mostly reserved for royal persons and kings (Bard, 2015).

Contrary to general assumptions, mummification in Peru can be dated much further back in time than in Egypt: among the oldest mummification practices is the Chinchorro mummification, which started as early as 6000 BC (B. T. Arriaza et al., 2005). The method of mummification is very different from Egyptian mummification techniques and has not changed and evolved quite as much over time. Between the Initial Period (from 1800 BC) and the beginning of colonialization by the Spanish conquest (1534 AD), the different techniques of mummification changed only slightly and can often be distinguished by the use of different colors or accessories. In general, the archaeological evidence suggests that the majority of mummies are characterized by natural mummification or intentional natural mummification. Intentional natural mummification means that the bodies were intentionally desiccated by warm or cold climatic conditions or intentionally wrapped in material that is very absorbent (Cockburn et al., 1998).

Melanesians have a particular preference for the preservation of the heads, which were described to have been mainly used as trophies (Cockburn et al., 1998). But the intentional mummification of whole bodies was also practiced in some places, such as Papua New Guinea, Torres Straits, New Caledonia and New Hebrides. Compared to the other two places of origin for mummies, Egypt and Peru, there are no mummies of very

old age in Melanesia. These mummies were most prominent in the 19th and early 20th century (Haslam et al., 2009). These mummies are characterized by intentional desiccation of the dead with the help of smoke, air draught and heat.

1.5 Embalming techniques in the different Egyptian dynasties

Mummification in Egypt probably started more than 4000 years ago and was practiced mainly along the banks of the Nile (David, 2008). It started with natural mummification, which over time became more elaborate culminating in artificial mummification (Shin & Bianucci, 2021). These changes in mummification techniques over time are described in more detail in the following chapters.

The chart below (Figure 1) shows various sites and some famous necropolis mentioned in the following subchapters about Egyptian time periods.



Figure 1. Map of major sites mentioned in the text [painted with Adobe Fresco and Adobe expert by Liesa Geppner].

1.5.1 Predynastic Period

The Predynastic Period can be divided in subgroups which represent different cultural and technological innovations or changes in climate. Dee et al. (2013) tried to create a classification on the basis of radiocarbon dates of organic materials. They described the Badarian and the Naqada Periods, with three junctures of particular archaeological significance: Naqada IA – IIB, Naqada IIC – IID and Naqada IIIA – IIIB. There is also a Naqada IIIC cultural period, but with a big overlap with the First Dynasty, which is why it is not mentioned here. Naqada IIC – IID is described as the time when burial practices from Abydos occurred in southern Saqqara (Dee et al., 2013).

According to Rosso (2014) , only mummification by natural processes was carried out in the Predynastic Period, as the contact with hot and dry sand was enough. Adams (1984) and Cockburn et al. (1998) describe, that the bodies were positioned in a crouched posture with arms and legs folded in shallow sand graves. The bodies were buried together with grave goods, like potteries. But slate plates with typical animal forms, such as birds or fish were also found. The warm sand and also the absence of rain desiccated the bodies and thus preserved them (Cockburn et al., 1998). So, no active embalming processes and no mummification of the body in the narrow sense took place and the bodies were just wrapped in cloths like linen or straw mats. According to that, no salt remains are detectable which accelerate the desiccation process and no openings at the bodies are visible in these kinds of mummies.

An example of these early burials suggests that in the Badarian Period (4400 to 4000 BC) in Egypt, the belief of immortality was established (Rosso, 2014). A grave at Mostagedda in Upper Egypt unraveled the remains of three children. Their faces were covered with leather pillows to insulate the face from the surrounding sand. But also other materials were used to cover the bodies. For example goatskins or woven matting or baskets was placed over their corpse (Rosso, 2014).

However, this perception that mummification in the Predynastic Period was only achieved by natural processes was rejected by Jones et al. (2014), who described microscopic and chemical evidence of resin in samples of textile wrappings from cemeteries at Badari (4400 to 4000 BC) and Mostagedda. This seems to be the oldest evidence of a concept of

an embalming recipe in Egypt, based on plant oil or animal fat with a lesser amount of conifer resin and aromatic plant extract and minor amounts of wax and plant sugar. Furthermore, Jones et al. (2014) described, that there is a change in the direction of spin of the woven yarn from a Z direction to a S twist yarn starting at the Naqada IB period. These scientific findings by Jones et al. (2014) push back the earliest evidences of mummification techniques by about 1500 years.

1.5.2 Early Dynastic Period

There are several different classifications of the Early Dynastic Period. According to Hassan (1980) the Archaic or Early Dynastic Period lasts from 3150 until 2700 BC. For this dating Hassan used calibrated C¹⁴-dates that are remarkably consistent and are satisfactorily in agreement with some approximate, indirect historical dates. This period is subdivided in two Dynasties; each of them are characterized by their reigning pharaohs.

A clear description of the characteristic embalming methods of this period is difficult, because only the body from one of those kings was found. And even the remains of King Djer's body at Umm el-Qaab, a necropolis near Abydos (a wrapped arm, radius and ulna, of a plundered tomb) is no longer existent (Adams, 1984; Aufderheide, 2003). Adams (1984) wrote, that these parts could also be from the Djer's queen, because of the bracelet and amethyst found near the arm. Jones (2007) describes the discovery of 85 fragments at Umm el-Qaab that can most probably be assigned to the royal tombs of Djer, Djet and Den of the First Dynasty. The study notes, that the majority of the fragments consists of tightly compacted layers of fine linen, up to about 100 layers in thickness (4.5 cm). The finer quality of the textiles was found very close to the body, while outer layers were made of coarser linen. The linen was impregnated with resin but no chemical analysis was made to identify the type of resin.

At Early Dynastic times, more and more coffin-like enclosures were used to protect the body from the animals of the deserts. This also minimized the effect of desiccation and permitted decomposition to occur (Dunand & Lichtenberg, 2006). Dunand & Lichtenberg (2006) describe that for the Egyptians at the early beginning of that period it was not quite

clear what effects the hot sand had on the preservation of the dead body. So just slowly, the artificial process of mummification developed, and the technique of wrapping linen band impregnated with resin around limbs and fingers was established. With the help of resin, body contours, as well as body hairs, tattoos and skin injuries could be preserved, because the resin became rigid after cooling and kept the body shape even though all soft tissue inside the body decomposed (Aufderheide, 2003).

Jones (2007) further mentions that a large part of the fragments found from this period are shiny, dark brown to black. This condition is caused by extremely high temperatures and suggests a fire in the burial chambers in ancient times.

1.5.3 Old Kingdom

The Old Kingdom with its five dynasties lasted from 2686 to 2160 years BC (Shaw, 2003). Regardless of the chronological details, David (2008) mentioned, that during this period mainly the outer appearance of the body was important in mummies. Limbs were separately wrapped in tight-fitting linen bandages, while the face, breasts and genitalia were shaped with a rubber substance and were finished with painted details. Unfortunately, in most cases bodies treated that way were unearthed in a fairly decomposed fashion.

Only at the beginning of the Fourth Dynasty the ancient Egyptians began to remove the organs from the bodies (Rosso, 2014). It was important to remove liver, lungs, intestines and stomach rapidly, because a few hours after death the soft tissue of the body begins to decompose, producing hydrogen sulfide, methane and other malodorous components which accelerate decomposition. Sometimes even the male genitals were formed with textile or sealed with resin. According to Adams (1984) these organs were stored separately but in the same grave, so that the body can be reassembled as a unit after life. Ikram (2010) also described that the bodies had been disinfected (in a few cases) with natron solution and/ or palm wine and were dried with powdered natron.

Koller et al. (1998) confirms the occurrence of embalming in the Old Kingdom based on chemical analysis of a mummy (ca. 2200 BC) in which sodium and wood tar compounds

were found. This itself prevented microbial contamination of the tissues to such an extent that the alkaline bone phosphatase was kept in an enzymatically and immunologically active form.

Lacovara et al. (2015) writes, that excerebration was not used during the Old Kingdom but evisceration was used at the end of the Third Dynasty and more frequently in the Fifth Dynasty. An example, given by Lavocara et al., is the burial of Queen Hetepheres, spouse of Sneferu, whose internal organs were found in a canopic chest preserved in a solution of natron.

In the Mastaba G 2220 B, one of the largest private tombs at Giza, a female mummy was found. Der Manuelian (2009) describes in his book *Mastabas of Nucleus Cemetery G 2100* how the mummy was buried and preserved. The body of the female mummy lies extended, arms and hands at the side, feet together, with the head to the north and slightly turned to the left side. Der Manuelian & Simpson (2009) cites the more detailed description of the mummy's wrapping from *Noel F. Wheeler's notes of January 21, 1933*. Therefore, the outer linen wrapping looks like a long dress with a V-shaped neck opening. Underneath, 10 cm wide strips of linen were found, which covered the body from the ankles to the neck, without removing the intestines, whereby the feet were wrapped with a 1 cm band, which was created by folding or twisting a wider band. The head is completely enveloped, the nose was molded and the cheeks were stuffed with pads. The outer linen sheets have 42 threads per cm and the inner wrappings were slightly coarser. In total the body was covered with about 37 layers of linen and hollows and irregularities were filled with pads to give the body a more lifelike appearance. Unfortunately, according to another report by Dr. Douglas Derry, a chemical analysis of the linen was not done, but it is assumed that it was strung with wet resin. Reisner (1942) dated this female mummy to the late Fourth Dynasty.

Mummies of this period often were dressed and covered with jewelry while some of them were coated with plaster. This layer of plaster was painted and served to restore the decayed parts. This stage of wrapping mummies with resin soaked linen associated with modeling and painting body parts, was mainly used in the Fifth and Sixth Dynasties, but has been further developed later (Rosso, 2014). An example for this mummification

techniques is the mummy of Nefer, discovered at Saqqara in 1966, dated to the Fifth Dynasty (Rosso, 2014). The mummy of Nefer had been coated with stucco plaster to represent his true facial characteristics with modeled and painted eyes, eyebrows, and a moustache on his upper lip: He wore a short haired wig as well as a false linen beard on his chin Figure 2.

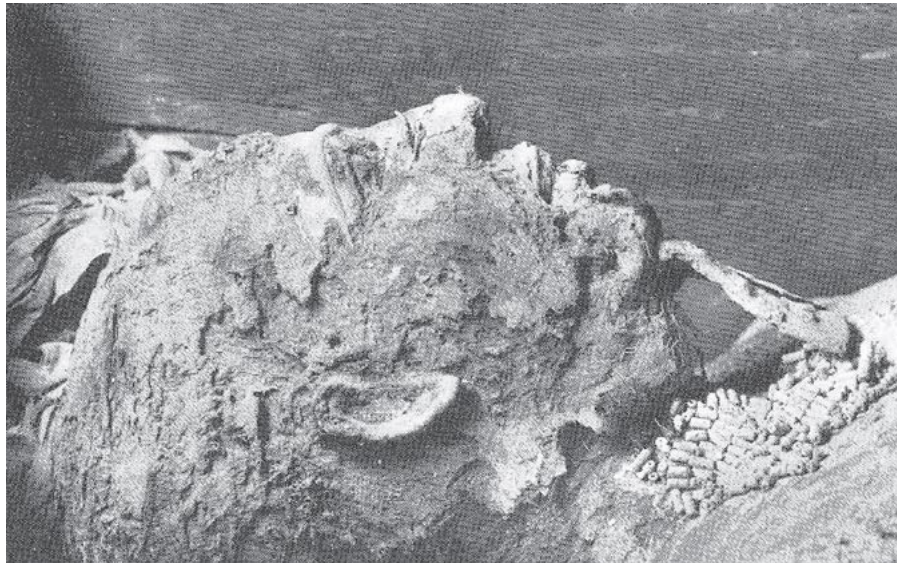


Figure 2. Nefer's facial modeling with stucco plastered linen, wig, false beard and beads – an example of the mummification process carried out during the Fifth and Sixth Dynasties (Adams, 1984, p.16).

Lacovara et al. (2015) describes the mummification process of a mummy from the Carlos Museum of Emory University, found at Abydos and dated on the Sixth Dynast. The body was placed in a slightly contracted position on the right side. Due to the fact that, although wrapped in linen and covered with an organic substance, this mummy lacks flesh, it can be assumed that the body decomposed due to insufficient evisceration and dehydration. A total of seven layers of linen could be seen, the outermost of which was made of fine warp-like fabric (with thread counts over 45 warps/cm) and towards the inside the linen became increasingly coarser. Ten to 12 cm wide pieces of linen were wrapped around the body and hands were wrapped like they were wearing mittens. Since the linen strips were very compressed, as Lacovara et al. (2015) describes it, it is assumed that they were soaked with the same substance that was used to cover the body.

1.5.4 First Intermediate Kingdom

This chapter describes the transition between the end of the Eighth Dynasty and the beginning of the reign of Mentuhotep II. Thus the First Intermediate Period ranges from the Ninth Dynasty to Dynasty 11a (first half of Dynasty 11), from 2160 to 2055 BC (Shaw, 2003).

1.5.4.1 Colored plaster masks, helmets and wigs in the First Intermediate Period (2160 – 2055 BC)

Another feature of this period is the appearance of colored masks made of plaster and linen to cover the mummies heads (Shaw, 2003). Kroenke (2010) describes the different manifestations of the mummy masks in the First Intermediate Period. In the Herakleopolitan Period cartonnage mummy masks covered the heads, shoulders and chests and were referred to as “helmet”. The typical length of these masks extended only over the chests, 20cm below the chin. Kroenke describes some masks (those of the tombs N.3765, N.3756b and N.4172) which were painted white at the front tabs and no inscriptions were found. The wig consisted of double strands of twisted linen threads, which were painted black and then attached to the mask. This wig technique is a feature of the First Intermediate Period. Some of them even were painted beards and moustaches and or false beards. Some of these were painted in blue to demonstrate the divine status (deities had hair made of lapis).

1.5.4.2 Mummification with natron and oils, evisceration and bandaging in the First Intermediate Period (2160 – 2055 BC)

Mummies from the First Intermediate Period were cured in natron, eviscerated and bandaged. Thereby the intestines were dried and buried separately in a canopic chest (Ikram, 2012). Ikram (2012) further mentions, that bandages were mostly made of spiral wrappings and both men and women had their arms placed on the sides of their thighs. Abdel-Maksoud & El-Amin (2011) writes, that evisceration achieved either by an incision in the abdominal wall or by an enema with juniper oil which was injected into the anus. When the oil was drained, the intestines and stomach also came out. Furthermore, they reported, that the embalmers of this period did know a lot about the specific

characteristics of unsaturated oils. It allows them to dry or polymerize the body by producing a physico-chemical barrier that impedes the activities of microorganisms. Natural oil or resin stopped dehydration and restored the epidermis' elasticity and preserved it from becoming brittle in the process (Rosso, 2014).

1.5.5 Middle Kingdom

The Middle Kingdom ranges from the 11th Dynasty to Dynasty 23, from 2055 to 1773 BC (Shaw, 2003).

1.5.5.1 Tripartite masks in the Middle Kingdom (2055 – 1773 BC)

According to Kroenke (2010), the common and standard private mummy mask of the Middle Kingdom, for both sexes, are tripartite wigs painted black or blue. Some examples of masks of male burials, show a striped head covering with bands of red, green and blue, separated by narrow stripes of yellow. These masks were found at the burials at Thebes, Kafr Ammar and Saqqara and were dated to the early Middle Kingdom. A characteristic feature of the mid 12th Dynasty, which differs from those of the First Intermediate Period and early Middle Kingdom, is the false beard with a chin strap and the lack of full beard and moustache.

1.5.5.2 Mummification with natron and resin, linen wrapping, sometimes evisceration and excerebration in the Middle Kingdom (2055 – 1773 BC)

Mummies from this time are sometimes very various, especially with regard to their methods. An example of a mummification method is given by six queens and princesses from the temples of Mentuhotep (Aufderheide, 2003). Adams (1984) describes one of these new techniques that emerged at the time of the Middle Kingdom. This was found on mummified princesses from the 11th Dynasty. Their bodies were possibly dried rapidly with dry natron, a salt naturally found in Egypt and composed of sodium carbonate and sodium chloride. This protected the tissues. The skin was then covered with resin. Their organs were not removed, but oleo-resin (akin to turpentine) was injected into the rectum and vagina to dissolve the organs.

Although until then mummification had only been intended for pharaohs and their fearful relatives, there were also findings of mummifications of members of the middle class during this period in the Middle Kingdom (Aufderheide, 2003). This is shown by a description of a finding by Gupta et al. (2008). Gupta et al (2008) reported on the tomb of Djehutynakht. Only a mummified head and a single finger have survived. The head, which is shown in Figure 3, is dated to the early days of the Middle Kingdom and is wrapped in molded linen and the eyebrows are painted with black pigment. The head shows one of the first brain removals in this period. This example is especially interesting because in the middle kingdom there are only very few findings that show excerebration. Some defects were found in the cranial bone, which could indicate brain removal. For example a defect in the ethmoid air cells and sphenoid sinus. Gupta et al. (2008) than argued, that a part of Djehutynakht's brain was removed through the nasal cavity. The brain fragmented were broken into smaller pieces by repeated flushing and the fragments were pulled out with a hooked probe. This made it possible to easily remove the front and middle brain tissue. The remaining brain tissue could then have been removed by enlargement of the foramen magnum. All of the taphonomical abnormalities, like the absence of the anterior walls of the maxillary sinuses and inferior orbital rims, were assumed to have happened through the different steps of excerebration (Chapman & Gupta, 2007).

Another feature characteristic of this period is resin, which is applied to the body. Compared to mummies from the Old Kingdom, resin was not applied to the wrappings, but on the body itself (Aufderheide, 2003).

Adams (1984) describes a technique, which is attributed to two bodies found in Saqqara and dated the 12th Dynasty, but is more similar to that of the New Kingdom. These bodies showed a removal of the organs except the heart. The cavity of the abdomen was stuffed with linen, the face was covered with resin and the nostrils were also plugged.

Another body from the 12th Dynasty had its nails tied on with thread to prevent their loss during decomposition, which became a common procedure in the Middle Kingdom (Adams, 1984).

Sheppard (2012) describes an uncommon method of the mummification process of the two brothers Khnum-Nakht and Nakht-Ankh from the 12th Dynasty. They were found at

Rifeh in a non-royal tomb. There are only a few years between the death of the two brothers but still the two were preserved using different methods. Khnum-Nakht died earlier, poorer and unexpectedly and his embalming methods consisted of quicklime, sodium and chloride salts and there is very little skin tissue left. Nakht-Ankh was wealthier and very well preserved with sulphates, soda and chlorides. Petersen et al. (2003) showed, that the mummification process at Nakht-Ankh was very effective, cause the skin lipids and protein was well preserved. However, Petersen also described that in spots where sodium sulfate was used for embalming, a higher degree of degradation of biomaterials in the skin is seen.



Figure 3. Mummified head of Djehutynakht, a local governor of the Middle Kingdom. The head is wrapped in molded linen and the eyebrows were painted. Defects in the cranial bone indicates brain removal (Gupta et al., 2008, p.706).

1.5.6 Second Intermediate Period

According to Franke (2008) the Second Intermediate Period ranged from Dynasty 13 (1795 BC) to Dynasty 17 (1550 BC).

1.5.6.1 *Rishi* coffins in the Second Intermediate Period (1795 – 1550 BC)

A very characteristic feature for the end of the Second Intermediate Period are the so-called *rishi* coffins, which are related to the mummy masks and developed in Thebes (Dodson, 2011). An essential feature of this anthropoid coffin was the feather pattern (*rishi* = Arabic for feather). The upper part of the coffin is decorated with a *nemes* headdress, the face is usually very simple, small and wedge-shaped. On the chest there is a painted *wesekh* collar with drop-shaped beads on which a vulture with outspread wings is painted and in some cases a cobra next to the vulture. The first layer of short schematic feathers is located at the chest. On the sides and at the legs the feathers become more realistic and longer (Miniaci, 2007). However, this description of *rishi* coffins may differ. For example, the vulture and the cobra are missing from the early *rishi* coffins, and the feathers are replaced by an abstract arrangement of circles. However, the *nemes* headdress with its feather decoration resembles the *rishi* mask. Thus the features of *rishi* coffins gradually emerge (Miniaci, 2007).

1.5.6.2 Mummification with resin, stuffed eyes and nose in the Second Intermediate Period (1795 – 1550 BC)

One of the most well-known mummies of this period is that of King Seqenenre (Aufderheide, 2003). It is assumed that King Seqenenre succumbed to his head injuries in the battle against the bearers of the Hyksos reign (Bietak & Strouhal, 1974). Shaw (2009) described the skeleton of Seqenenre (Figure 4), which is covered by a moist, dark brown layer. It has an aromatic, spicy smell caused by powdered sawdust that has been spread over the body. Furthermore, no natron was used for dehydration, the brain has not been removed and the skull has not been stuffed. However, the organs were removed by cutting the body on the left side and removing heart and lungs. But this area was not packed with linen. Aufderheide (2003) explains the sloppiness of this mummification with

the reason that the body was probably embalmed very quickly on the battlefield, where the king died of his injuries.

An Egyptian mummified head from the Slovak National Museum in Bratislava, gives some new impressions about the method of mummification in the Second Intermediate Period. In a paper from Šefčáková et al. (2005) the skull is dated to the 15th Dynasty, although the mummification techniques that were applied to this skull were used until the end of the New Kingdom and therefore an earlier dating cannot be excluded.

Šefčáková et al. (2005) further describes, that the nasal septum, the conchae and the posterior upper wall of the nasal cavity are largely damaged. The eye sockets were stuffed with coarsely woven linen rolls. However, no artificial eyes were inserted. The oral cavity was also filled with a coarsely woven linen roll. In the right quarter of the occipital region, CT scans revealed a crumpled material, possibly soaked in resin, which was introduced into the empty cranial cavity through the nostril after brain removal.

Resin residues are also found on the surface of the skull, which can be noticed by the deep grey to black coloring, the shimmer and the specific smell.

Unfortunately, only few examples of artificial mummification are available for study, therefore knowledge of mummification techniques is limited in the second intermediate period.



Figure 4. Pharaoh Seqenenre Tao II with many fatal injuries at the head (Bietak & Strouhal, 1974, Tafel 3). The head is covered by a moist dark brown layer and the brain was not removed.

1.5.7 New Kingdom Period

The New Kingdom Period ranged from 1539 to 1077 BC and is divided in three Dynasties (Dynasty 18 to Dynasty 20) (Hornung et al., 2006). In the New Kingdom mummification techniques were perfected. These mummification techniques could be reconstructed in detail because of the many Pharaohs, which were found in this period (Pommerening, 2015).

1.5.7.1 *Rishi* coffins, anthropoid coffins and painted and gilded cartonnage masks in the New Kingdom (1539 – 1077 BC)

At the beginning of the 18th Dynasty the development of the *rishi* prototype proceeds. A New Kingdom coffin from the 18th Dynasty, found in Saqqara, shows the development of the *rishi* coffins. This coffin does not show canonic feathered decoration. In addition to two normal vertical bands, which also occurred in earlier times, there are two additional

vertical bands with a " basket weave" pattern and the feather decoration is limited to the side and lower parts of the lid of the coffin (Miniaci, 2007).

Hawass & Richards (2007) use a drawing with a color scheme to show a small section of what the color pattern of a *rishi* type coffin looks like. This piece is part of a badly decomposed coffin from a cemetery at Giza, from the early 18th Dynasty. On one side there is a column of text in green hieroglyphs, separated by green lines. In the middle there are polychrome diamond fields in red, yellow, black and green over a white background. The scale pattern is painted in yellow, red and pale green, with black outlines (Figure 5).

Taylor (1996) describes the mummy mask from Satdjehuty and the analogy to the *rishi*-coffins. Due to the absence of a beard, one can assume that the mask belongs to a woman. Queen Satdjehuty was the wife of King Ahmose I from the early 18th Dynasty. This mummy mask from Queen Satdjehuty can be seen in the British Museum (Museum number: EA 29770, https://www.britishmuseum.org/collection/object/Y_EA29770) and is constructed from cartonnage and consists of a mixture of blue, white, gold and red colors. The face is small, oval, and bird-like, eyes and ears are well-defined, with arching eyebrows and cosmetic eyelines. The headdress has the shape of a bird, like a falcon or vulture and is framing the face. Around the neck, there is a *wesekh* collar with 14 rows of tubular beads and an outer row with drop-shaped beads. Taylor (1996) further mentions that the color scheme of the mask is very similar to the anthropoid coffins used during the reign of Tuthmosis I – III.

One of the most known and best preserved mummy masks is that of Tutankhamun. The striped *nemes*-headdress is made of linen and is decorated with alternating gold and blue glass paste. A vulture and a winged cobra are sitting on the forehead. At his chin he has a long false beard with a curved end made of gold and grey-blue glass paste. The curved eyebrows and eye lines are inlaid with blue glass paste. On the chest there is a multi-level collar with 12 rows of beads of blue glass paste, turquoise, amazonite and carnelian (Uda et al., 2007).

Cooney (2014) gives a small overview of the development of the anthropoid coffins during the New Kingdom, which can be dated very well by their background color. A white

background color is typical for the early 18th Dynasty and a shiny black background color indicates the middle to end of the 18th Dynasty (Thutmosis III and later). At the time of the late 18th Dynasty the color yellow was very dominant respectively a gilding on the most expensive coffins, shiny pistachio varnish on the upper layer or yellow ochre on the cheapest coffins. In addition, arms and hands were also carved on the surface of the coffin at this time. This color scheme lasted until the early 22nd Dynasty. At the beginning of the 19th Dynasty the decorations became more complicated, with polychrome scenes. In the 20th Dynasty complicated Book of the Dead and Amduat imagery were added, especially on the side walls of the coffins, and towards the end of the 20th Dynasty polychrome scenes were used inside the coffin for the first time.



Figure 5. Yellow-ocher, red-brown, green, white, black colored fragment of a *rishi* coffin at Giza.
[Painted with Adobe Fresco by Liesa Geppner, based on Hawass & Richards (2007)].

1.5.7.2 Mummification with natron, resin and linen, excerebration and facial painting in the New Kingdom (1539 – 1077 BC)

The 70-day mummification process in the New Kingdom can be divided into four steps:

1. *Operative stage*

In the so called 'House of Beauty' the first process involved the purification of the dead body and the excerebration, which was carried out using a method similar to that already used in the Middle Kingdom. A metal rod was inserted into the nostrils and through the ethmoid bone to reduce the brain to fragments, in order to be able to remove the brain parts more easily (Rosso, 2014). A rather atypical method was to extract the brain through

the foramen magnum or a trepanned orbit (David, 2008). It takes several days for the remaining fluid to drain from the brain. Hot liquid resin is then poured into the cranial cavity. Sometimes dry linen is also stuffed into it. But there are also mummies where neither of these was done (Aufderheide, 2003). For the Egyptians the brain did not play a major role. According to their belief, the heart is the part that is responsible for the personality. That is why the brain was often completely disposed of and not stored (David, 2008). A study by Saleem & Hawass (2013) goes into more detail on the excerebration process of kings in the 18th to 20th Dynasty. According to this, the skulls of the three kings Thutmosis I, II and III from the 18th Dynasty did not show any intercranial embalming (the desiccated brain could be seen on CT-images) which suggests that the brain was not removed. Another six royal Kings (Amenhotep III, Akhenaten, Seti I, Ramesses II, Merenptah, Ramesses III) dated between the late 18th to the early 20th Dynasty showed evidence of transnasal excerebration. Saleem & Hawass (2013) also detected, that from the 19th to 20th Dynasties cranial packs got larger and showed more variability than those in the 18th Dynasty.

In a next step the viscera were removed from the thoracic and abdominal cavities. A cut on the left side of the abdomen was made to remove the lower organs (kidneys were usually left inside), then the diaphragm was opened to remove all the contents from the chest cavity (excluding the heart, which was believed to be the seat of the thoughts) (Rosso, 2014). The viscera was then preserved with natron and wrapped in resin-soaked linen and placed in special containers called canopic jar. After these processes of excerebration and evisceration the body was cleaned with palm wine and spices to sterilize the body cavity. A few days later the body was ready for the desiccation process (Aufderheide, 2003).

2. Desiccation stage

Now all the inserted linen was removed, and new natron-soaked linen was replaced. A linen band around the head and jaw prevented the mandible from slipping. After this, the body was laid on pulverized natron and got completely covered by dry natron to a depth of at least 5 cm. To prevent skin-to-skin contact, linen filled with natron, was placed in the axillae, between upper thighs and external genitalia (Aufderheide, 2003). This process

lasted for around 40 days und resulted in a much darker skin color because of the resin application (Rosso, 2014).

3. Waterproofing and cosmetic stage

Now the natron from the skin, the surface and the body cavity were removed. According to Aufderheide (2003), the cavity was then rinsed with palm wine und cavity surface painted with hot liquid resin. After this, much liquid resin was poured in the cavity to sterilize it and to seal all openings. The wound was usually not sutured. Most gaps were left open, sometimes the lips of the wounds were stuffed with a linen cloth soaked in resin and only in rare cases a metal plate was placed over the wound. Body openings like nares, external auditory channel, anus and vagina were closed with a resin soaked linen tampon. The eyes were usually left in the orbit and resin-soaked linen was placed over them. Sometimes metal plates helped to keep the eyelids in position. Also, the defects in the nasal cavity were usually closed with linen patches soaked in resin. Fingernails and toenails were tied to the fingers and teeth respectively. For royal bodies, golden thimbles were often used. The skin surface was then anointed with cedar oil or other aromatic oils like myrrh. Then the entire body was coated with hot liquid resin to make it water repellent. Sometimes beeswax was added to enhance the effect. Afterwards the body was decorated with various jewelry and amulets (Aufderheide, 2003).

4. Wrapping stage

Aufderheide (2003) describes in the last step how the deceased was wrapped in linen. For the limbs, fingers and toes were first wrapped individually and then hands and feet were wrapped. At the arm, broader strips of linen were first applied lengthwise and then circular strips with hot resin were wrapped around the hand. A similar procedure was used for the feet. The penis was also wrapped separately and sometimes formed with resin-impregnated linen. Then broader pieces of linen were used to wrap the arms together with the torso and both feet were also wrapped together. In women, sometimes the breasts were formed with linen bands and the outer circular bands were often painted red. Finally, in some cases eyes, eyebrows and mouth were painted on the outer linen layer. This entire ritual took 15 days.

The mummy was then placed in a coffin with the hands at the sides. Later, the hands were folded over the chest. This practice lasted until the late 20th Dynasty (Rosso, 2014).

Bianucci et al. (2008) describes the mummification technique of two 18th Dynasty mummies, Kha and his spouse Merit, from Thebes. In both mummies the brain is still visible in the skull and no internal organs were removed, although excerebration and evisceration was a standard method during the New Kingdom. Kah's textile wrapping consisted of animal fat and plant oil with small amounts of aromatic plant extract, plant gum and conifer resin. While Merit's mummy wrapping consisted of fish oil and small amounts of aromatic plant extract, plant gum, conifer resin and beeswax.

A study by Wade et al. (2011) examined the frequency of transnasal craniotomy and found an incidence of 50-66% during the New Kingdom. Only during the Ptolemaic and Roman Periods there is a very high rate of transnasal craniotomy with up to 90%.

The very famous mummy of Tutankhamun is wrapped in cotton wool and linen bandages. The internal organs were replaced by clothes soaked in consecration unguents, and the sternum and most of the ribs were also removed. Furthermore, there is a dense mass of solidified resin in the pelvis (Harrison & Abdalla, 1972). Tut's body was eviscerated, but with a diagonal cut from the navel toward the left iliac crest. A common procedure for this time was an incision along the iliac crest. The penis was also mummified, but not in a flaccid state, but in an erect state (Rühli & Ikram, 2014). The king's brain was removed through the nose, which destroyed the nasal septum, the ethmoidal cells and the cribriform plate (Shafik et al., 2008). Then the skull was filled with resin. It is somewhat uncommon that the skull was filled with resin twice. Possible reasons could have been that the first deposit was insufficient or it was due to the forgetfulness of the embalmer, or the uncovered areas were repaired the second time, or there were two steps of embalming at this time (Ikram, 2013).

Saleem & Hawass (2015) gives some facts about subcutaneous packing in 13 mummies from the 18th to 20th Dynasty, most of them kings of this period (Thutmose I, II, III, Amenhotep III, Tutankhamun, Seti I, Ramesses II, Merenptah, Ramesses III). He examined the subcutaneous fillings in the face, neck, torso and extremities. The most frequent subcutaneous packings are found in the face (11 of 13 mummies show such fillings). Only

five out of 13 mummies show packings in the torso and only four mummies show packings in the neck or extremities. In the face, the packs were mainly used to model the natural facial contours. This means that material was mainly found around the nose, the cheeks and in the jaws. Furthermore Saleem & Hawass (2015) found out that in the New Kingdom subcutaneous packings in hands and feet are more common than in the 21st to 22nd Dynasty.

Saleem & Hawass (2015) give a more detailed description of the mummy of Ramesses III from the 20th Dynasty. The skull shows evidence of excerebration via the left nostril and a stuffing with a resinous material of two thirds of the skull. The nose is filled with embalming material as well as the orbits and oral cavity. Through an oblique incision in the left inguinal region, all intestines except the heart were removed. This abdominal cavity was filled with linen, resin and a heterogeneous low density embalming material. The penis was also covered with superficial linen shreds impregnated with resin. Limbs are wrapped separately with several layers of impregnated linen and arms are crossed over the chest with hands flat.

1.5.8 Third Intermediate Period

The Third Intermediate Period ranged from 1069 to 656 BC and is divided in five Dynasties: Dynasty 21 to Dynasty 25 (Shaw, 2003).

According to Shaw (2003) the mummification and preparation reached its peak with the beginning of the 21st Dynasty. However, due to socio-economic stress, the effort in high-cost embalming is reduced during the 22nd Dynasty and the bodies are treated more perfunctorily (Cooney, 2012).

1.5.8.1 Cartonnage wrapping in the Third Intermediate Period (1069 – 656 BC)

While the value for the ritual of embalming increased in the 21st Dynasty, the value of the coffin decreases. This may be due to the fact that coffins of the dead were often reused for the next deceased. As a result, the coffin no longer represents an imperishable image of the dead body and thus loses its appeal. The elite families who could afford such

embalming rituals thus decided to focus on the human body and invest less in tombs and gilded coffins (Cooney, 2012).

A change in embalming techniques in the middle of the 22nd Dynasty brought a new type of mortuary container, now made of cartonnage. This new wrapping is a cheaper and easier to produce. Cartonnage wrappings fit tightly around the corpse and are tied at the back. This resulted in fewer thefts, as the material was difficult to reuse and was also not as expensive. With the help of painted cartonnages, they tried to present the corpse in a lifelike and immortalized way (Cooney, 2012).

1.5.8.2 Mummification with natron and resin, subcutaneous packing, evisceration and reshaping of facial features in the Third Intermediate Period (1069 – 656 BC)

The 21st Dynasty marks a renewed improvement in the mummification technique. Badr (2015) examines five mummies of the 21st Dynasty and describes their mummification techniques. These innovative embalming techniques are also described by Aufderheide (2003) and Cooney (2012).

Although the methods used in the past had in some cases already produced a well-preserved mummified mummy, this often no longer resembled the actual form of the embalmed person. While in the New Kingdom the skin of the deceased still looked slack and drawn, attempts were made in the Third Intermediate Period to prevent the shrinking of the skin and thus the scrawny appearance to make the deceased look more alive.

Using the method of subcutaneous packaging, different materials such as sawdust, linen or sand are stuffed into the space to force the skin outwards. With an incision on the left side of the abdomen, the internal organs were removed and then treated with natron. Afterwards, resin-soaked packing material was forced through this incision into the thighs and legs up to the ankles. In order to be able to fill all areas, sometimes further incisions were made in the body. The neck area was also filled with packing material through the incision of the evisceration. The intestines were then placed back into the body in their original position. The arms were also filled with resin-soaked packing material through an incision in the shoulder. Figure 6 gives an overview of the different incisions which were

made at the body and the way in which the stuffing material was placed in the body (Badr, 2015).

While in previous dynasties the mummies were often presented as sleeping, in the 21st Dynasty realistic-looking artificial eyes are often modelled to make the mummy look awake. Furthermore, the entire body is painted. For women, the color yellow was chosen and men were painted red. Life-like wigs were also often used at this time. These can be made of real human or artificial hair (Cooney, 2012).

According to Cooney (2012), the early Third Intermediate Period is the only time period in Egyptian history where the increasing development of mummification had a high economic, aesthetic, religious and social value. Until the beginning of the 22nd Dynasty, the high standard of mummification technique is maintained but by the middle of the 22nd Dynasty, mummification becomes more careless even for the elite. Methods such as evisceration and drying of the internal organs and reinsertion into the body remained the same, but there was no longer any emphasis on creating a realistic, lifelike body. As a result, features such as the inlaid eyes, the stuffed extremities, the realistically recreated face and the painted applications are absent.

Cooney (2012) gives a possible reason for the change in mummification technique in the Third Intermediate Period: In ancient Egyptian ritual scenes, mummies are not displayed without external protection, such as wrappings, masks or a coffin, during burial ceremonies. Thus, the expensive and elaborate mummification method of the elite could only be witnessed in a small circle of relatives. For the big ceremony, the body was then bandaged and covered. The body, in which so much money and effort had been invested, could thus not be shown to the large audience. This made the great investment in embalming invisible and probably therefore this method of treatment was dropped.

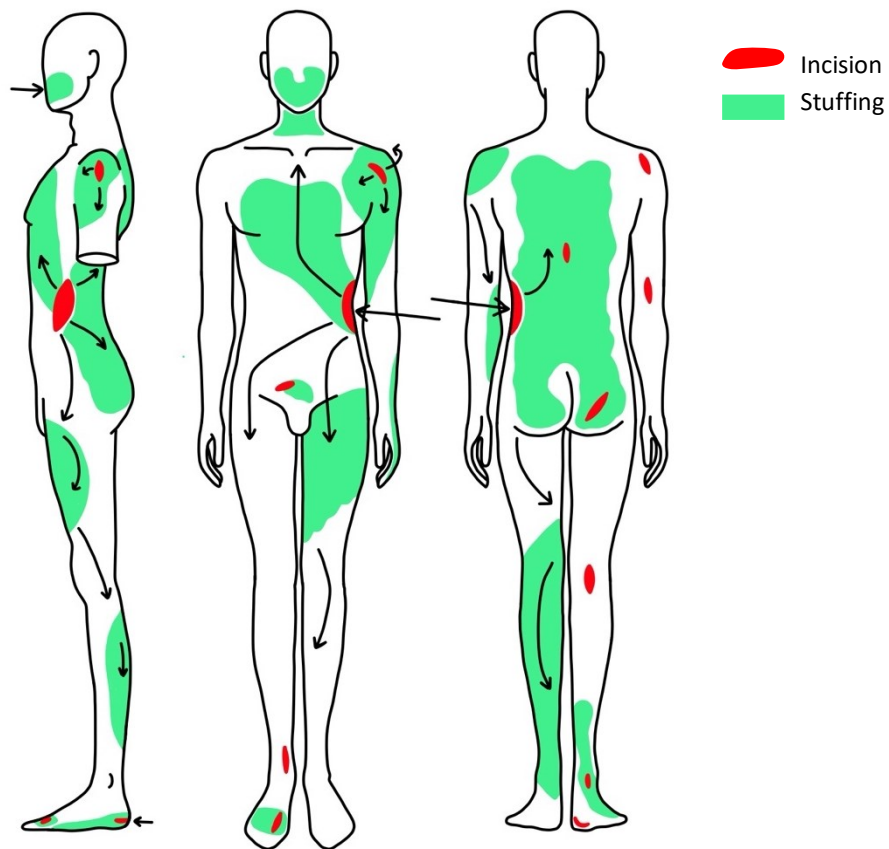


Figure 6. Illustration of subcutaneous packing shows incisions and the way the body was stuffed.
[Painted with Adobe Fresco by Liesa Geppner, based on Badr (2015)].

1.5.9 Late Period

The late Period ranged from 664 to 332 BC and is divided in five Dynasties (Dynasty 26 to Dynasty 30) and the 2nd Persian Period (Leahy, 2020).

The high standards of mummification techniques established during the Third Intermediate Period start to decline again during the Late Period (David, 2008). David also writes that the subcutaneous packing and painting of the skin is decreasing. In addition, the treatment of the viscera changes. For the most part, they are no longer placed back in the body, but either in canopic jars (as it was common in earlier dynasties) or between the legs. Due to the fact that the external appearance of the mummy in the Late Period was more important than the actual body preservation, many of the mummies from this period are less well preserved due to incomplete dehydration.

Due to the small amount of mummies found in the Late Period, not much information is available about the mummification method in this period. Loynes (2015) describes the technique of embalming and preparation for the afterlife based on seven mummies. Since these remains all relate to the 26th Dynasty, this is the only representation of this period. The finds are mostly from Thebes and only one examined mummy comes from Akhmim.

Five out of seven of these mummies show excerebration through the trans-nasal route (four via ethmoid and one via sphenoid) and in one mummy the brain was removed through the trans-orbital route. In this new trans-orbital route method, excerebration occurs from the orbital roof into the middle cranial fossa via a horizontal route. Only one mummy shows no excerebration. In the mummies where excerebration was performed via ethmoid there are no material remains in the skull visible. In the case of those excerebration routes through the sphenoid or the orbit, resinous remains were found in the skull. In five mummies linen packing on the eye globes were applied to generate artificial eyes and in one case eye plates were used (Loynes, 2015).

For five mummies, the technique of treating the trunk could be analyzed and all of them show an incision in the left abdomen and a retrained mediastinum. The viscera were returned to the body cavity in two cases and in two other cases they were placed in canopic jars. In one mummy a determination was not possible (Loynes, 2015).

In summary, Loynes (2015) describes, that excerebration was carried out via a variety of routes, whereas cranial packaging was less common. However, eyes and mouth were often stuffed with material, but subcutaneous packing in the neck region was no longer used. Evisceration was also continued through a left incision in the abdomen.

1.5.10 Ptolemaic Period

The Ptolemaic Period started when Alexander "the Great" defeated the Persians in 332 BC. When Alexander died in 323 BC, the Macedonian Dynasty continued under his name until 305. Ptolemy then assumed control of the Egyptian Empire and ruled with his successors until the Roman conquest in 30 BC (Muhs, 2016). One of the most famous

female personalities in the Egyptian Era, Cleopatra VII, Pharaoh in the Ptolemaic Period, is also known from this period (Shaw, 2003).

Due to the fact that the Ptolemaic Dynasty was ruled by foreign rulers, changes in mummification methods occurred, where the religious factor became less important and the commercial factor more important in mummification. These circumstances lead to a decline in the standard of mummification (David, 2008). According to David (2008), there is more focus on the outer wrapping of the mummy and less attention on the preservation of the body. Sometimes the viscera were removed and prepared and either put back into the body or the body cavity was filled with resin. The most important embalming material used at this time was resin, and various parts of the body were preserved with this material resulting in the characteristically dark, hard and shiny surface.

Similar to the Late Period, Loynes (2015) describes the technique of embalming and preparation for the afterlife based on nine mummies. In eight out of nine mummies, excerebration was performed via the trans-nasal route. Five of the eight mummies have resinous remains inside the skull. In comparison to the previous period, the eyes of seven mummies were desiccated, one mummy had its eyes removed and only one mummy had its eyes stuffed with linen. Five cases show treatment of the mouth with filling material like resin or linen, the others show no filling. Subcutaneous packing of the neck does not occur in any mummy. Eight of the nine mummies examined show evisceration, in six cases this was done by an incision on the left abdomen and in two cases the perineal route was chosen. Some mummies had an incision in the perineal region in addition to the incision in the abdomen. Four cases show preservation of the mediastinum, while three mummies show complete evisceration and in one case no evisceration was present. In this time period, the viscera were mostly not put back into the body, placed in a canopic jar. The body cavity in most cases was treated with resin.

In summary, Loynes (2015) describes, that excerebration was carried out using the trans-nasal route. In this time period resin was much more used as a cranial filler but eyes were not packed or covered with eye plates and half of the cases showed stuffed mouth. It was continued to use the left abdomen for evisceration but with an additional use of the perineal approach and the body cavity was in most cases filled with resin.

1.5.11 Roman Period

The Roman Period starts with the Julio-Claudian Dynasty, which begins with the ruler Augustus (also called Gaius Octavianus) and extends to the ruler Nero (Lightfoot, 2000). Egypt was now part of the Roman Empire, which begins in 30 BC and ends in 394 AD, four centuries later (Shaw, 2003).

According to Aufderheide (2003), the methods of mummification are similar between the Ptolemaic and Roman Periods. However, a very unique feature of the Roman Period is the appearance of portraits of the deceased for the first time.

1.5.11.1 Mummification with resin and linen, stuffing and excerebration in the Roman Period (30 BC – 394 AD)

Loynes (2015) describes the mummification method in the Roman Period using 17 mummies. The majority of the mummies (11 cases) show excerebration via a trans-nasal route. Only four mummies show a lack of excerebration. In two mummies a less common route was chosen, one via the foramen magnum and one via a trans-orbital route. The occurrence of cranial packing is very variable. Eight out of 13 mummies that also show excerebration show cranial packing in form of resin and in one mummy in form of granular material. The eyes were in most cases (13 out of 17) left in the body and are desiccated. Only in three cases the eyes were treated with resin or linen and in one case the eyes were removed. Filling material in the mouth can be seen in 9 out of 17 mummies. The material used is mainly resin or linen. With regard to evisceration, there is no unique form of treatment. Half of the mummies examined show no wounds that indicate evisceration, while the other half show an incision in the abdomen, a perineal incision or both. In only five cases the viscera were returned as a canopic package, in all others the viscera are no longer present. Treatment of the intestines was done with resin, linen or granular material.

In summary, Loynes (2015) analysis suggests that there is a change in the performance of excerebration and evisceration due to a change in the practice of mummification during the Roman Period.

Riggs (2012) also describes the mummification method during the Roman Period. She writes that the mummies were skillfully wrapped with geometrically applied bandages and buried with painted portraits or with gilded and painted stucco masks. Furthermore, in most cases excerebration and evisceration were carried out and resin and linen were used as embalming material.

1.5.11.2 Stucco masks and portraits in the Roman Period (30 BC – 394 AD)

As in the previous periods, mummy masks are also common during the Roman Period. However, during the end of the Ptolemaic period, the mummy masks have changed so that elements of fashion and coiffure began to emerge on the mummy mask. The mask was usually made of stucco and often also covered with linen or cartonnage. Sometimes the masks are also made of wood. Details such as ears, eyes and the top of the head were added individually. The mask was then covered with finer stucco and hair, beards or similar fine details were added. Finally, the mask was painted and gilded (Riggs, 2012).

Riggs (2002) explains the difference between portrait and mummy mask. According to this, a portrait is a representation that refers to a two-dimensional, drawn image that is supposed to contain lifelike features of the individual. On the other hand, there is the mummy mask, which is a three-dimensional modelled object that is fitted to the head and chest of the mummy.

The bandaged corpses were often decorated with a painted wooden portrait or a gilded painted stucco mask. The faces were not painted in profile, as was often the case with earlier paintings, but the person is looking directly at the viewer and a bust view was chosen (Aufderheide, 2003). According to Aufderheide (2003), most of the realistic portraits found from the Roman Period were dated between 50 AD and 250 AD, only a few were found later and after 350 AD there is no more evidence for painted portraits.

Riggs (2012) describes that the portraits were often painted on the outermost layer of the linen wrapping of the mummy, or more frequently even on thin panels of wood. Because the portraits are very naturalistic and individualistic, they are often compared to modern portraits. Because most portraits were removed from the mummy wrappings and often

exhibited separately in museums, there is a false assumption that the portraits were painted during the lifetime of the deceased.

1.5.12 End of mummification in Egypt

Mayer & Reed (2012) write that the method of embalming bodies was performed until around AD 650. With the appearance of Christianity subsequent to the Roman Period, there is a further decline in the standards for embalming. The reason for this is that Christians rejected the practice because they associated it with pagan religious rites. According to David (2008), the bodies were no longer eviscerated, but the body was still treated with natron and other substances and then covered with clothes and linen sheets.

Embalming was also rejected with the conquest of Egypt by the Arabs in 641 AD. The Muslim rite stipulates that the corpses should be buried until the next day, unpreserved, washed and wrapped in shrouds. For this, the body is handed over to the decomposing soil or the drying sands of the desert (Pommerening, 2015).

1.6 Embalming techniques in Peru

Looking at Peru, a general chronological division can be made into different cultural periods. Table 1 gives an overview of these different phases, which refer to the central Andes (Cockburn et al., 1998, but see other chronologies in new publications). One of the oldest cultures with its own mortuary techniques can be dated back to the Preceramic Period, which is also one of the oldest records of mummification in the world (Arriaza, 1996). According to Guillén (2004) the oldest naturally mummified body, which can be attributed to the Chinchorro culture, can be dated back to around 9000 BC. Mummification in Peru came to an end in the Colonial Period with little continuity of mummification practice at the beginning of the colonial period, including a few mummification discoveries dating to the late 18th century. Some time periods of Peruvian history with interesting and important mummification techniques of different Peruvian cultures will be discussed in more detail in the following subsections.

Table 1. Cultural Periods for the central Andes in Peru (Cockburn et al., 1998).

Period	Time
Preceramic Period	20000 – 1800 BC
Initial Period	1800 – 900 BC
Early Horizon Period	900 – 200 BC
Early Intermediate Period	200 BC – 600 AD
Middle Horizon Period	600 – 1000 AD
Late Intermediate Period	1000 – 1476 AD
Late Horizon Period	1476 – 1534 AD
Colonial Period	1534 – 18 th century AD

1.6.1 Preceramic Period

The first artificial mummifications began already around 9,000 years ago BC. However, due to the desert-like environment, there were also natural mummifications for

thousands of years (Allison, 1996). This natural mummification occurs mainly in two periods from 7000 BC to 6000 BC and from 1880 BC to 1500 BC. This type of mummification results from the aridity of the environment (Arriaza, 1995). Arriaza (1996) describes also artificial mummification, which can be attributed to the Chinchorro culture and was performed between 7000 and 1500 BC. Within the Chinchorro culture, different types of artificial mummification have become established. These can be classified as Black, Red, Bandage or Mud-coated mummies. They overlapped in time.

Arriaza (1995) gives a brief overview of these different mummification techniques, summarized below:

1.6.1.1 Chinchorro Black mummies (5860 – 2090 BC)

These represent one of the most complex mummification techniques. Before starting the actual mummification, the trunk was separated from the head, arms and legs and all organs were removed. Facial skin and the ears were also removed and desiccated, for later replacement. The brain was removed through the foramen magnum and the skull filled with grass, ashes, soil or animal hair. The entire body was then modelled with an ash paste and sticks and ropes are also embedded to recreate the original shape as lifelike as possible. Facial skin and ears are also embedded in this ash paste. Finally, the body is painted with manganese, resulted in this black appearance and the eyes, nose and mouth were remodeled. Figure 7 (A and B) shows how the body of these Black mummies were remodeled. This mummification technique persisted for 3770 years (5860 to 2090 BC) (Arriaza, 1995). A picture from Arriaza et al. (2008) shows the appearance of a Black mummy (Figure 8 A).

1.6.1.2 Chinchorro Red mummies, some with wigs, contemporary to black mummies (5860 – 2090 BC)

As with the black mummy, the body was dissected to remove the most important organs and muscles. The head shows excerebration similar to the black mummy and was dried with ashes and then often real hair wigs up to 60 cm in length were attached to the occipital region. The face was covered with a white ash paste over which the facial skin was placed and then the face was painted and modeled with a black manganese paste

or a dark red ochre paste to create a kind of face mask. The body was also strengthened with sticks that were tied together at the neck and inserted through the foramen magnum to reattach the head as well (see Figure 7 C and D). The body was stuffed with ash, camel hair, feathers, grass, animal skins or soil and the incisions were sewn shut with cactus needles, human hair or plant threads. Finally, the body was painted completely, this time with red ochre, leaving the black face mask unchanged. The black mummy in comparison has no incisions or seams, as the body was completely disarticulated. These differences of appearance is shown in Figure 7 B. As with the Black mummies this mummification method persisted for 3770 years (5860 to 2090 BC) (Arriaza, 1995). A picture from Arriaza et al. (2008) shows the appearance of a Red mummy (Figure 8 B).

1.6.1.3 Chinchorro Bandage mummies (5860 – 1720 BC)

This type of mummy is a similar variant to the red mummies. Characteristics that remain the same are the red painting, the wearing of the human hair wig and the longitudinal rods for reinforcement (Arriaza, 1995). In addition, these mummies have bandages, which can also be made of sea lion or pelican skin. This mummification method persisted for 4140 years (5860 to 1720 BC) (Arriaza, 1996). Figure 9 A shows the appearance of a Bandage mummy (Arriaza, 1996).

1.6.1.4 Chinchorro Mud-coated mummies (5860 – 1720 BC)

Another embalming method is used for the mud-coated mummies. The bodies were first smoked and then dried with hot coals. Then the corpse was covered with a 1-2 cm thick layer of mud. This mud consists of blood, sand and sometimes plant fibres. In this method, no rods were used to reinforce the body. Some mummies of this type show evisceration, others do not. As with the Bandage mummies this mummification method persisted for 4140 years (5860 to 1720 BC) (Arriaza, 1995). Figure 9 B shows the appearance of a Mud-coated mummy (Arriaza, 1996).

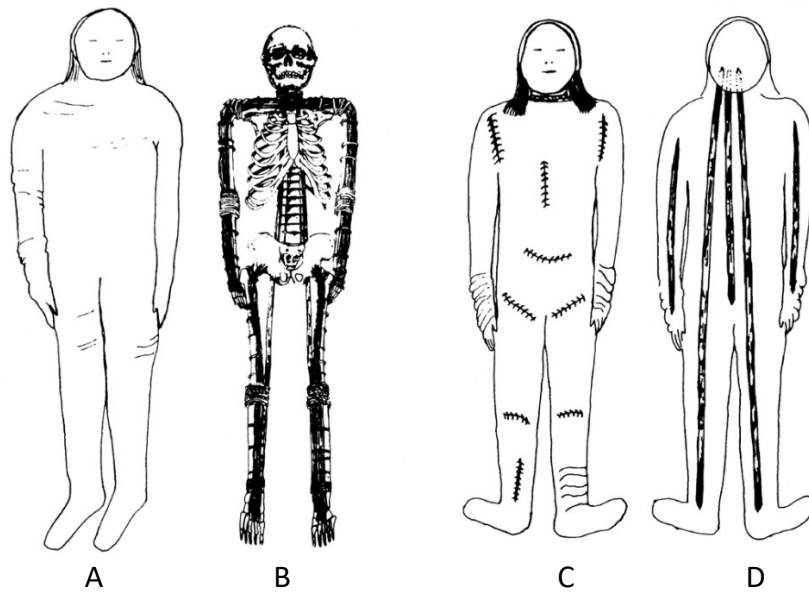


Figure 7. External and internal representation of the embalming process of a Black mummy (A and B) and of a Red mummy (C and D) (Arriaza, 1995)



A



B

Figure 8. Picture of a Black mummy (A) and a Red mummy (B). Reproduction with courtesy of Bernardo Arriaza (Arriaza et al., 2008, p.52).



A



B

Figure 9. Picture of a Bandage mummy (A) and a Mud-coated mummy (B). Reproduction with courtesy of Bernardo Arriaza (Arriaza, 1996, p. 136).

1.6.2 Early Horizon to early Intermediate Period

Cockburn et al. (1998) describes that there has been a big change in the mummification technique in the period between the Early Horizon (900 – 200 BC) and Early Intermediate Periods (100 BC – 600 AD).

The mummy bundles from Paracas are an example for this. In this process, one, or in some cases several, dead bodies were usually placed in a basket in a sitting and bent position and covered with several layers of textiles in such a way that mummy bundles are created. The mummies from Paracas have a very characteristic skull deformation, in which boards were laced on the front and back of the skull during the growth period to achieve an elongated shape of the skull (De León, 2017; Gómez-Mejía et al., 2022). In the case of the elite mummies, artificial mummification probably took place, including evisceration and removal of some muscle parts and the use of chemical substances for preservation. Due to the high salinity of the soil, the constant coastal wind, the high position of the corpses above the groundwater and the constant exposure to the sun's heat, artificial mummification was often not necessary and therefore natural mummification was found in most cases (Cockburn et al., 1998).

1.6.3 Middle Horizon Period

Mummies that can be assigned to this Middle Horizon Period (600 – 1000 AD) are also packed in mummy bundles. The body is usually tightly flexed and covered with shrouds. The body was then covered with layers of cotton lint, linen and tightly interworked cord superstructures to form a bundle. The head was also recreated from layers of fabric and had eyes and nose made of metal or shells, real hair wigs, a woven cap or a sling headband. On top of the mummy bundle, a tapestry tunic was placed. These many layers of wrapping led to good preservation, as these absorbent cottons were able to draw off bodily fluids well. These features of burial continued in some regions and with a few variations even until the Spanish Conquest (Cockburn et al., 1998).

1.6.4 Late Intermediate Period

The mummification techniques of the Late Intermediate Period (1000 – 1476 AD) can be observed in different cultures. The mummification techniques of Chiribaya, Chancay or Chimu mummies are discussed in this context.

According to Jeremiah (2014) mummies of this time period were all found in flexed positions, had their knees drawn up against their chest and the hand touched their faces. Arms and legs were bound to keep the mummy bundle in position. On top of these bundles often some kind of fake heads or death masks were placed.

The Chiribaya culture flourished between 900 – 1350 AD in the Late Intermediate period. Almost all of these mummies were preserved naturally. Bodies, that were preserved for the afterlife show abdominal cuts for evisceration and cleaning.

Afterwards the body was filled with raw wool and food, like corn, sweet potato and coca leaves and the incision was closed with a wool yarn. This process was done in a very short time period, because no evidence of fly and/ or beetle activities can be found in these mummies. The skin was cleaned to prevent insect activities, but otherwise no embalming material was applied and in many artificially prepared mummies, over time the outer wrapping has been replaced or covered with a new cloak (Guillén, 2004).

Another key culture of the Late Intermediate Period is the Chancay culture, lasting from 1000 – 1470 AD (Cowie & Johnson, 2002). Mummies of the Chancay people are wrapped in seated position in many layers of cloth, which can be referred to as a mummy bundle. Furthermore, these mummies wear a wooden mask, also called a “false head”, which has the shape of a flattened head (Bakula et al., 2000). Figure 10 A shows one of these masks, that were often tied on the bundles and showed simplified features, with wide, diamond-shaped eyes, a long straight nose and some masks even included a wig of hair (*Mummy Mask with Wig*, n.d.).

Compared to this culture, the highly sophisticated Chimu mummies (flourished between 1100 – 1400 AD) were adorned with elaborate ornaments, like a metal mummy mask. These mummies were buried in crouching position and covered with layers of fine cotton. Some of the metal ornaments were also sewn into the fabric wrappings of the

mummy head. Figure 10 shows a comparison between the Chancay and the Chimu mummy mask (Cowie & Johnson, 2002).



Figure 10. Comparison of the two very different mummy masks:
(A) wooden mask of a Chancay mummy, 61.355 (*Mummy Mask with Wig*, n.d.) and (B) metal mask of a Chimu mummy (© Wikimedia Commons; https://commons.wikimedia.org/wiki/File:Chim%C3%BA,_mummy_mask,_gold,_Dayton_Art_Institute.JPG).

1.6.5 Late Horizon Period

During the Late Horizon Period (1476 – 1534 AD) the famous “Inca mummies” appeared in Peru. The many mummy finds associated to the Chachapoya culture (800 – 1470 AD), active during the previous Late Intermediate Period, and called “warriors of the clouds” by the later Inca are particularly characteristic of the Late Horizon Period. This is because the Chachapoya mortuary behavior is important for understanding the Inca culture (Guillén, 2004). On page 152 of Guillén (2004) she shows a typical Chachapoya mummy, wrapped in bundles, tied up with rope and covered with cotton cloth.

Since no discovered Chachapoya mummy had the smell of a natural mummy, but an antiseptic smell, it can be assumed, that these mummies were all artificially prepared

(Guillén, 2004). The effect of this mummification process was a dried, tightly bound, light and compact package, which is easy to transport. A very unusual step was the way of evisceration. For this, the anus was enlarged in order to remove intestines. Afterwards this area was cleaned and dried and the opening was filled with cloth plugs. Native plants such as *poleo* and *muña* were probably used as preservation substances. Raw cotton was used to fill the nostrils, the inside of the cheeks and the inside of the mouth. Finally, the body was wrapped with several layers of cotton cloths, often stitched with specific Chachapoya patterns (Guillén, 2004).

These Chachapoyan mummification techniques were continued by the Incas. Modifications included the adoption of other material culture and intentional mummification practices (Dalton et al., 2021).

For the Inca, it was important that the mummified bodies simulated life, as their belief was that the dead continued to participate in the world of the living (Cohen Suarez & George, 2011). To achieve this, they were buried in a sitting position with their legs crossed, arms folded over their chests and their heads turned slightly downwards. The face, for example, was so well preserved because there was a calabash rind under the skin of the cheeks. This ensured that the skin remained firm and did not lose its shine. The artificially formed eyes were open to emphasize the lifelike appearance of the deceased.

It is assumed that the corpses were treated with a chemical substance to promote desiccation. Another possibility of mummification is that the bodies were taken to high altitude areas with permanent freezing temperatures in order to completely dry out the skin. Later they were brought back to complete the mummification process and form the traditional mummy bundles (Cohen Suarez & George, 2011). This process included the removal of the intestines and the heart. At the end of the mummification process, the bodies were dressed and placed on stretchers decorated with feathers and gold (Heaney, 2021).

The bodies of the former rulers were carefully embalmed to remove all body fluids. This was especially important because these royal corpses were touched particularly often and, according to belief, had to last for eternity. This made the corpses so light that they

could be handled without any problems. For the poorer people and those of the common folk, there was often no embalming, as the process was too time-consuming and complicated and would have needed to be carried out by professionals (Cohen Suarez & George, 2011).

An example of an Inca mummy is given by Cardin (2015) and Cockburn et al. (1998). They describe a very interesting mummy finding from the Andes Mountains in Peru. This mummy got the name “Inca Ice Maiden”, because this is about a frozen body of a young girl. The cold temperatures in the Andes resulted in a naturally mummified body, with the internal organs, her skin hair, eyelashes and wrapping material very well preserved. Gold and silver statues decorated with feathers were associated with this mummy; so it is suspected that this was probably an offering to the gods.

1.6.6 Colonial Period

The Colonial Period (1534 – 18th century AD) is marked by the Spanish conquest. The Andean mummification practice ended with the Spanish conquest of the Inca empire in 1534. The Spanish saw the mummies and the Inca culture as a religious and political threat to the Christian rule. To destroy the Inca culture, the Spanish conquistadores and priests ordered mummies to be destroyed, burned or buried. This was carried out to establish their Catholic religion (Bauer, 2021; Cockburn et al., 1998).

1.7 Embalming techniques in Melanesia

The description of mummification practices in Melanesia is more complex than in the countries mentioned above. This is because, on the one hand, ethnographic reports provide very different approaches and, on the other hand, mummification was not performed as a single death ritual, but was included in many different cultural rites. However, mummification was practiced only by a few tribal groups. Compared to the previously described mummification techniques from Egypt and Peru, the mummies from Melanesia are not of great antiquity. This is because mummification was not used to preserve the body for eternity, but only for a few years or less. Therefore, it is very difficult to study ancient mummies from this region. Some information about mummification techniques has survived and is available from New Guinea, New Caledonia and the Torres Strait Islands (Cockburn et al., 1998). Furthermore, the death ritual of the New Hebrides is very interesting with regard to this thesis and is therefore also described in more detail.

1.7.1 Mummification in Papua New Guinea

In Papua New Guinea smoked body mummification is the traditional preparation of the deceased people of the Anga culture, also known as the “Kukukuku”. This still-living culture is the only one that still practices anthropogenic mummification today. For the Anga people, there is no life after death, but they believe that the deceased live in the world after death as a kind of "spirit". Therefore, this mummification ritual is practiced because the Anga believe that the spiritual connection to the dead is lost when the body is no longer recognizable due to decay. In 2015, this type of mummification is documented for the first time in New Guinea in a natural cultural setting, where mummification took place as follows (Shin & Bianucci, 2021; Stone, 2016):

At the beginning, the deceased is observed for three to five days. In this specific case seven men were selected to perform mummification.

After that, the deceased got undressed and was placed on a chair over a smoky fire in a hut. A Kuyeka bristle plant, used to express and absorb body fluids, was

applied to remove the epidermis layer and hair. In addition, body fluids are manually squeezed out from punctured holes in the skin of the deceased.

The next step is smoking, which can take between 30 and 60 days until the body is completely dry. When the body is sufficiently dehydrated, the corpse is placed on a new chair and covered with red ochre clay. This ochre clay is also used to extract any remaining fluid from the body. Finally, a stick is inserted into the rectum to ensure that the intestine does not retain any fluids.

In the final step, the completely dehydrated body is dressed in traditional style in a sitting position at the chair and placed among the other ancestors. A further ceremonial application of red ochre clay follows, which is supposed to give the deceased protection from the environment and further dehydrate the body.

1.7.2 Mummification in Torres Straits

While in New Guinea, smoking over fires was the most common method of drying the dead, in Torres Straits the bodies were dried in the open (Cockburn et al., 1998). The following mummification technique of Torres Straits is described by Haddon et al. (1935). First the body had to lay for four to five days. Then the epidermis was peeled off and an incision was made in the side of the abdomen to remove all the intestines. The deceased men also had their palms and soles pulled off and their tongues cut off. This procedure was not done for the women. To remove the brain, a cut was made through the base of the skull and with the help of an arrow, the brain was removed through the foramen magnum. Then dried sago-palm was used to stuff the body and support it from contracting and the incision was sewn up. Human strength was also used, trying to squeeze the remaining body fluids out of the body. When the body was almost completely dry it was decorated, nautilus shell was used to represent the eyes and the body was smeared with red ochre and coconut oil. The body was then hung once more over the smoke or fire to finish the drying process. This process of complete drying could take several months. Finally, the finished mummies were tied on a frame in the garden

of the deceased spouse. If the mummy fell to pieces over time, only the head was kept (Haddon et al., 1935).

1.7.3 Mummification in New Caledonia

As a common practice in the Faténaoué mummies of New Caledonia, which is also the case with Oceanic mummies, like the ones from New Guinea, the epidermis was removed (Haslam et al., 2009). However, very unusual and uncommon in other oceanic mummies is the fact that no body part was removed from the body, the thorax was not opened, the neck was not intentionally disarticulated, and the New Caledonia mummies do not appear that any efforts were made to restore the living human appearance, as is the case with the Torres Straits or Vanuatu mummies. The method of desiccation in the Faténaoué mummies in New Caledonia is due to high exposure to the sun and/or low heat and smoke exposure. The bodies were decorated, but there is no evidence of clothing or painting. While in Torres Straits the bodies were bound on a frame or on chairs as in Papua New Guinea culture, the Faténaoué used baskets in which the mummies were kept. Based on available information, it is concluded that this type of mummification began before the 19th century and was still active at the turn of the 20th century and disappeared after European colonization (Haslam et al., 2009).

1.7.4 Mummification in New Hebrides

Although the preparation of the New Hebridean skulls seems very similar to mummies, these skulls are not mummies because the skin and soft parts are entirely removed and therefore, there is no preservation of the soft tissue (Flower, 1882). However, due to the similarity of these New Hebridean skulls to mummy skulls and the fact that there is a mummy skull at the Natural History Museum that looks very similar to this technique, these skulls are also briefly described here.

The New Hebridean (Vanuatu) skulls are often called "memorial heads" or "overmodeled skulls". Before they get the typical appearance, they are cleaned. In most

cases, the head is buried temporarily until the soft parts decompose. Then the skull is cleaned and any remaining soft parts are removed. If the brain has also decomposed, no further procedures were undertaken to open the skull. If the brain was not yet completely decomposed, the brain was removed through an opening at the base of the occipital bone. During modeling, the face is covered with a thick layer of clay up to the upper part of the forehead. This substance is made from shredded plant fibers mixed with a rubber-like substance such as clay. This completely covers the facial bones and is used to model the facial features. The supraciliary ridges do not show bulging, which would emphasize the prominence of the superciliary ridges, but they are pronounced at least to some extent. The ridge of the nose is usually shaped to be almost in line with the backward slope of the forehead and the nostrils are pronounced. The cheeks are also usually rather prominent. The lips have a wide opening, so that the teeth can be seen, and the ears are represented in a very rough shape and placed where the auricles actually use to be. The eyes are shown only very schematically. They are represented by a deep oval or in some cases round hole. The surface of these modelled skulls is smooth and has a dark reddish brown, sometimes almost black color. The author describes skulls that have a black coloration that looks like a stripe, extending from each eye backwards and below the ear to the neck, others have a black band-like discoloration over the forehead (Cameron, 1919; Flower, 1882). Figure 11 shows a typical New Hebridean skull with clay covering the facial part up to the upper part of the forehead (Wellcome Collection, n.d.)

The skulls of this regions have a very unusual skull shape. Rüdinger (1888) describes this intentional modification of the New Hebridean (Vanuatu) skulls to have a long cylindrical skull shape, which is the result of a circular lacing that starts at the forehead and continues upwards and backwards wrapped around the head during the first years of life. This type of skull shape is also known as circumferential intentional deformation (Buikstra & Ubelaker, 1994).



Figure 11. Typical New Hebridean skull with the facial part covered with clay (Wellcome Collection, n.d.).

1.8 Summary of embalming techniques: Sequence of events

Based on literature references of different mummification methods at different times in the different countries, an overview has been compiled below showing the different techniques of mummification in the countries of Egypt, Peru and Melanesia. This overview refers to the literature research cited in the introduction.

Table 2 lists the different mummification techniques used in Egypt. A distinction was made between the individual dynasties and the predominant embalming technique used during this period was described. This shows that during the first periods, mummification was still carried out in a very primitive way. From the Second Intermediate Period onwards, the mummification technique starts to become a little more elaborate. Evisceration and excerebration were carried out and more effort were invested in giving the deceased a lifelike appearance.

The different techniques of mummification in Peru are shown in Table 3. A distinction can be made between different periods, which have different mummification types. One of the oldest and already very elaborate mummification techniques are those of the Chinchorro culture, to which the black, red, bandage and mud-coated mummies belong. Compared to Egyptian mummies, those of the Peruvians are often wrapped in mummy bundles. Information on excerebration and evisceration is unfortunately often not given in the literature.

Table 4 gives a small overview of a selection of different mummification treatments on four different island territories in Melanesia. The difference between these mummification techniques and those in Egypt or Peru is that they are not of great age and the desiccation was often accomplished with the help of smoke, air draught and heat.

Table 2. Overview of the different mummification techniques used in the different Egyptian time periods.

Egyptian time period		Mummification technique in Egypt							Literature
Period	Years BC/AD	Excerebration	Evisceration	Stuffing	Subcutaneous packing	Wrapping material	Desiccation process/material	Reshaping of facial features	
Predynastic Period	4350 – 3075 BC	No	No	No	No	Goatskin, woven matting, baskets, leather pillows	Natural mummification	No	Cockburn et al. (1998); Rosso (2014)
Early Dynastic Period	3150 – 2700 BC	No	No	No	No	Linen wrapping	Begin of artificial mummification Impregnation with resin	No	Dunand & Lichtenberg (2006); Jones (2007)
Old Kingdom	2686 – 2160 BC	No	Yes	No	No	Linen	Sodium and wood tar components	Yes, with gummy substance + painted	Adams (1984); Koller et al. (1998); Lacovara et al. (2015); Rosso (2014)
First Intermediate Period	2160 – 2055 BC	?	Yes	No	No	Bandages of spiral wrapping	Cured in natron, usage of natural oil and resin	Colored mask of plaster and linen	Abdel-Maksoud & El-Amin (2011); Ikram (2012); Rosso (2014)
Middle Kingdom	2055 – 1773 BC	Yes	No	No	No	Wrapped in linen	Salt, natron, resin was applied on the skin (not to the wrapping)	?	Adams (1984); Aufderheide (2003); Gupta et al. (2008)
Second Intermediate Period	1795 – 1550 BC	No	Yes	Stuffing through nose	No	?	Resin	Eye socket and oral cavity stuffed with linen rolls, no artificial eyes inserted;	Šefčáková et al. (2005); Shaw (2009)
New Kingdom	1539 – 1077 BC	Yes, trans-nasal	Yes	Body cavities closed with resin soaked linen	No	Wrapped in linen bands	Natron, resin	Eyes, eyebrows and mouth painted on outer linen layer	Aufderheide (2003); David (2008); Rosso (2014)
Third Intermediate Period	1069 – 656 BC	?	Yes, organs back in the body	No	Yes, with sawdust, linen, sand	Cartonnage wrapping	Natron, resin	Artificial eyes, body painting (women = yellow, men = red)	Badr (2015); Cooney (2012)
Late Period	664 – 332 BC	Yes, trans-nasal	Yes, left abdomen	Yes	No	?	?	Mouth stuffing, linen packing /eye plates in the eye globes	David (2008); Loynes (2015)
Ptolemaic Period	332 – 305 BC	Yes, trans-nasal	Yes, left abdomen, perineal	?	No	?	Resin	Sometimes mouth stuffing	David (2008); Loynes (2015)
Roman Period	30 BC – 394 AD	Yes, trans-nasal	Sometimes yes, left abdomen, perineal	Sometimes yes	No	Bandaging	Resin, linen	Sometimes mouth stuffing and eye treatment	Loynes (2015); Riggs (2012)

Table 3. Overview of the different mummification techniques used in the different Peruvian time periods.

Peruvian time period		Mummification technique in Peru							Literature
Period	Years BC/AD	Mummy type	Excere-bration	Evisceration	Stuffing	Wrapping material	Desiccation process/material	Reshaping of facial features	
Preceramic Period	5860 – 2090 BC	Black mummies	Yes	Yes	Head filled with grass, ashes, soil or animal hair	Body was painted with magnese (black)	Body modeled with ash paste, sticks and ropes for perfect reshaping	Facial skin and ears were desiccated for later replacement	Arriaza (1995); Arriaza (1996)
	5860 – 2090 BC	Red mummies	Yes	Yes, sewn with cactus needles/ human hair/ plant threads	Stuffed with ash, camel hair, feathers, grass, animal skins or soil	Body was painted with red ochre, except the head	Body strengthened with sticks, tied together at the neck and put into the foramen magnum	Real hair wig, black painted an modeled face mask	
	5860 – 1720 BC	Bandage mummies	Yes	Yes	?	Bandages, sea lion or pelican skin, red painting	Longitudinal rods	Human hair wig	
	5860 – 1720 BC	Mud coated mummies	?	Sometimes	?	Body covered with 1-2 cm thick mud	Bodies were smoked and dried with hot coals, no rods	?	
Early Horizon to Early Intermediate Period	900 BC – 600 AD		?	Yes, in elite mummies	?	Mummy bundles, several layers of textiles	Natural mummification due to: high salinity of soil, coastal wind, position above the groundwater and constant exposure to sun	Elongated shape of the skull	Cockburn et al. (1998); De León (2017); Gómez-Mejía et al. (2022)
Middle Horizon Period	600 – 1000 AD		?	?	?	Mummy bundles, tightly flexed and covered with cotton shrouds	Absorbent cottons were able to draw off bodily fluids well	Eyes and nose made of metal or shells, real hair wigs	Cockburn et al. (1998)
Late Intermediate Period	900 – 1350 AD	Chiribaya culture	?	Yes, sewn with a wool yarn	Filled with raw wool and food, like corn, sweet potato and coca leaves	Covered with cloak	Most show natural mummification, no embalming material applied	?	Bakula et al. (2000); Cowie & Johnson (2002); Ginger (2021); Guillén (2004); Jeremiah (2014)
	1000 – 1470 AD	Chancay culture	?	?	?	Mummy bundles, wrapped in many layers of cloths	?	Wooden masks: wide, diamond-shaped eyes, long straight nose, sometimes hair wig	
	1100 – 1400 AD	Chimu culture	?	?	?	Covered with layers of fine cotton	?	Metal mummy mask	
Late Horizon Period	800 – 1470 AD	Chachapoya mummies	?	Yes, through anus	Anus stuffed with cloth plugs	Wrapped in bundles, tied up with rope and covered with cotton cloth	Artificially prepared: Native plants such as <i>poleo</i> and <i>muña</i>	?	Cohen Suarez & George (2011); Guillén (2004)
	1476 – 1534 AD	Inca culture	?	Yes	?	Mummy bundles	Chemical substances; some bodies desiccated with permanent freezing temperatures	Calabash rind under the skin of the cheeks, opened artificially formed eyes	

Table 4. Overview of some different mummification techniques used in the Melanesia.

Melanesia time period		Mummification technique in Melanesia						Literature
Island region	Years BC/AD	Excerebration	Evisceration	Stuffing	Wrapping material	Desiccation process/material	Reshaping of facial features/ skull deformation	
Papua New Guinea	Until today	?	?	No	Body covered with red ochre clay	Smoked over fire, Kuyeka bristle plant used to express and absorb body fluids	No	Shin & Bianucci (2021); Stone (2016)
Torres Straits	?	Yes, through foramen magnum	Yes, left abdomen	Stuffing with dried sago-pal, incisions sewn up	Body smeared with red ochre and coconut oil, mummies were tied on frames	Dried in the open, Epidermis was peeled off; for men: palms and soles pulled off, tongues gut off	Nautilus shells to represent eyes	Haddon et al. (1935)
New Caledonia	Before 19 th century – until 20 th century	No	No	No	Mummy were set in baskets	Desiccation due to high exposure to the sun and/or low heat and smoke exposure; Removal of epidermis	No	Haslam et al. (2009)
New Hebrides	?	Yes, if the brain is not decomposed it was removed through the foramen magnum	?	No	Covering with a thick layer of clay: made from shredded plant fibres mixed with a rubber-like substance such as clay	This is not a real mummy, no preservation of soft tissues: skull is buried temporarily until the soft parts decomposed	Shaping of facial features with clay; circumferential intentional modification	Cameron (1919); Flower (1882); Rüdinger (1888)

2 Material and Methods

2.1 Material and Inventory book

The purpose of this work was to shed light on the origin and the mummification processes of the until now un- or ill-identified mummies of the Department of Anthropology in the Natural History Museum Vienna. In the first step the inventory books of the anthropological collection of skeletons – called OSTE: including eight books with the inventory numbers 1 to 24958 – was used to identify and classify the mummies and to obtain information about each individual provenance and morphological features. Preliminary work had been carried out by Ella Fischer, who searched the inventory book for mummy descriptions and was already able to assign 23 out of 48 inventory book entries on mummies to mummified remains of the Department. According to this, 16 cases, which were described in the inventory book as mummy skulls, could be assigned to already skeletonized skulls (without, or only with very little embalming material or soft tissue left) (Table 5, highlighted in blue). They are named skeletonized skulls in this thesis. Further 20 inventory numbers can be associated to human remains with evidence of mummified tissues. From those, this work focuses on nine mummified remains (Table 5, highlighted in green), corresponding to the selection criteria (see below).

Information on each individual's provenance and morphological features was first retrieved from the inventory book. Because the inventory book was written in German, both the German description and an English translation were given by this candidate. There are eight inventory volumes in total, five of which contain information on the examined skulls and heads: the inventory book of the anthropological collection of skeletons - OSTE: book 1 (no. 1 - 1470), book 2 (no. 1461 - 2894), book 4 (no. 4783 - 9610), book 5 (no. 9611 - 5099) and book 6 (no. 15100 - 21316). However, to facilitate reading, when not mentioned explicitly, the inventory book in singular refers to any of the volumes.

All originally mummified human remains described in the inventory books are listed in Table 5 with the corresponding inclusion and exclusion criteria.

Since the focus of this work lies on mummy skulls or heads, **all other mummified human and non-human remains were not analyzed** in this study. This led to the exclusion of the following inventory numbers: 29 (mummified right arm), 2873 (plaster cast of the skull with the inventory number 2872), 9475 (mummified thorax), 15379 (mummified bird) and 15380 (mummified cat).

The mummy with the number 5 "The Clay Face" did not have an inventory number on the skull or the box where it was packed. Furthermore, it could not be assigned to a matching entry in the inventory book until now. Therefore, the internal inventory number "5" was assigned to this mummy.

Furthermore, skulls that were classified as **ethically questionable were not** further examined in this work. This led to the exclusion of the skull of the French officer with the inventory number 15377, which has already been described in a previous publication (Szilvassy & Kentner, 1978). Furthermore, the decision was made to exclude those skulls from further examinations that were directly connected with unethical provenance, such as **war events** or the **National Socialist context**. This is because the objects could not be treated according to the recommendations of the Deutscher Museumsbund (Deutsches Zentrum Kulturgutverluste, 2019), due to time constraints. Thus, the mummified head with the inventory number 20498 was excluded, because Otto Engländer, the man who sold this mummy to the Natural History Museum, was politically persecuted during National Socialism. Furthermore, the mummified remains of the Chilean soldiers of Gran Chaco (inventory numbers 20991, 20993, 20994, 20995, 20996) were also excluded from further studies, because they can be associated with war events, are presumably recent and are all expected to be the result of natural mummification. Finally, the mummified remains of a newborn (inventory number 9782) were also **not further examined** in this work, as there were **insufficient parts** available for these analyses. Last but not least, mummified **skulls with holes for suspension** were also **excluded** from more detailed examinations. Since these holes suggest that they could have been used by source communities as displays or in rituals, they would require special ethical approaches.

Not all mummified remains found in the Department of Anthropology could be assigned to a specific number in the inventory book. These specimens had either no inventory

number written on their containers or their wrapping materials, or the indicated inventory did not correspond to that in the inventory book. Therefore, new numbers were generated, which ranged from one to 14.

Table 5 shows, that some further mummified remains were excluded from further investigation for the same reasons as described above. These included the following internal inventory numbers: 1 (Peruvian child already published by Vyslozil (2000), 2 (mummified leg), 4 (mummified skull with hole for suspension), 6 (mummified skull with bast and a hole for suspension), 8 (plaster cast of a calotte), 9 (plaster cast of a calotte), 10 (mummified leg), 11 (mummified skull with holes for suspension), 12 (mummified leg), 13 (mummified remains without skull), 14 (mummified remains without skull), 15 (mummified skull with holes for suspension).

There are some human remains which appeared after the practical examination of the others was already finished. These individuals would still belong in this thesis, but could not be examined due to time constraints (Table 5, highlighted in red). One of these specimens has no inventory number and has not yet been assigned to an internal one. This refers to the mummy of a fully preserved Egyptian princess. This object has already been investigated several times and represented at exhibitions (Routil, 1950). Another object, that would still belong to this work, is the mummified head with the internal inventory number 7. Two more mummy entries were also found in the inventory book in later times. This refers to the inventory numbers 1520 and 1521, which are listed in the inventory book with the description "probably of mummies". Due to the fact that the practical work had already been completed, these objects could also no longer be examined.

Table 5. Overview of all inventory numbers originally described as mummies in the inventory books of the Department of Anthropology of the Natural History Museum in Vienna: inclusion and exclusion criteria. The color code green marks the mummified head, the color blue marks those individuals that used to be mummies but are now skeletonized. Individuals highlighted in red were detected in the Department after the practical work of the present thesis was already concluded. All individuals not highlighted in color were excluded from this study.

Inventory number/ individual inventory number *	Investigated in this study (yes/no)	Inclusion/exclusion criteria
-	No	Not analyzed due to time constraints: mummified body of princess
1	No	Mummified child, existing publication (O. Vyslozil et al., 2000)
2	No	Mummified leg
4	No	Mummified skull with holes for suspension
5	Yes	Mummified head, "The Clay Face"
6	No	Mummified skull with holes for suspension
7*	No	Not analyzed due to time constraints: mummified head
8*	No	Plaster cast
9*	No	Plaster cast
10*	No	Mummified leg
11*	No	Skeletonized skull with holes for suspension
12*	No	Mummified leg
13*	No	Mummified remains without skull
14*	No	Mummified remains without skull
15*	No	Mummified skull with holes for suspension
28	Yes	Mummified head
1520	No	Not analyzed due to time constraints: probably mummified head
1521	No	Not analyzed due to time constraints: probably mummified head
1522	No	Missing
1523	Yes	Today skeletonized skull
1524	No	Missing
1525	Yes	Today skeletonized skull
1526	Yes	Today skeletonized skull

2229	Yes	Today skeletonized skull
2231	Yes	Today skeletonized skull
2478	Yes	Mummified head
2859	Yes	Today skeletonized skull
2871	Yes	Today skeletonized skull
2872	Yes	Today skeletonized skull
2873	No	Plaster cast of #2872
2874	Yes	Today skeletonized skull
2875	Yes	Today skeletonized skull
2876	Yes	Mummified head
2877	Yes	Today skeletonized skull
4912	Yes	Today skeletonized skull
5036	Yes	Today skeletonized skull
5037	Yes	Today skeletonized skull
5042	Yes	Today skeletonized skull
5043	Yes	Mummified head
5877	Yes	Mummified head
9200	Yes	Mummified head
9475	No	Mummified thorax
9782	No	Mummified calotte of a newborn
14726	Yes	Mummified head
15377	No	Mummified skull, ethically questionable
15378	Yes	Mummified head
15379	No	Mummified bird
15380	No	Mummified cat
20498	No	Mummified skull from Otto Engländer, NS context
20991	No	Mummified head of Chilean soldiers, war event
20992	No	Skeletonized skull of Chilean soldiers, war event
20993	No	Mummified head of Chilean soldiers, war event
20994	No	Mummified leg of Chilean soldiers, war event
20995	No	Mummified leg of Chilean soldiers, war event
20996	No	Mummified arm of Chilean soldiers, war event

2.2 Further archive research in the Department of Anthropology of the NHM

2.2.1 Card catalogue of Collectors

The library of the Department of Anthropology of the Natural History Museum in Vienna also contains a card catalogue about the collectors. This catalogue lists the names of the collectors and which inventory numbers were collected by them. In addition, some entries mention years of the inventory, the year of the post number of the inventory book, or the date on which the object came to the museum. Unfortunately, there is no information on the date of the creation of the card catalogue, but since the card catalogue of the collectors was created parallel to the inventory book, it can be assumed that this happened in the second half of the 20th century. This catalogue was searched in order to compare the entries with the inventory book and potentially obtain additional information.

2.2.2 Somatological collection

The somatological collection is part of the collections of the Department of Anthropology of the Natural History Museum in Vienna. This contains field research records, protocols, documents, illustrations and manuscripts relating to research and collection activities, mainly of then living persons. Among these are measurement sheets, hair samples, skin strip findings, facial casts of different groups of people and standardized photographic images of different people and races (Szilvassy, 1976).

Some of the boxes were searched to obtain further information on the mummified remains described in this work. These included the boxes with the inventory numbers 2709/1 and 2709/2 which included information on sites from which some of the examined mummies originated (El Kubanieh, Giza).

2.2.3 Data base

The database (under construction in 2022) of the Department of Anthropology of the Natural History Museum was also searched for information and entries about mummies. All entries containing the word "mummy" were checked and compared with the findings herein.

2.2.4 Archive research

Further research was undertaken in various archival records to get more information about the provenance of the skulls. Unfortunately, no further results were found during this research. These archival records include the search for mummy records in the preliminary database of the Department of Anthropology of the Natural History Museum updated as of 18th February 2021, as well as the card catalogue, which was searched for further records on mummies. In addition, a database extract on mummies by Dominik Riedl from the Department Archive for the history of Science with the status as of 6th August 2019 did not provide any useful information. The Somatological Collection also provided no further information on the mummified remains.

2.3 International scientific cooperation

With the help of international scientific cooperation, valuable information could be exchanged and uncertainties regarding geographical, pathological and taphonomic findings could be clarified.

Discussions were conducted with a total of four scientists via Zoom or e-mail. One of them is Bernardo Arriaza from the University of Tarapacá, who is a specialist in the Chinchorro culture. Jamie Dau, from the Museum am Rothenbaum in Hamburg, is a provenance researcher and Maria Fernanda Boza Cuadros, from the Centro Peruano de Arqueología Marítima y Subacuática, is a Peruvian anthropological and historical archaeologist. These three scientists helped to assign uncertain mummy skulls to a country and to differentiate the sexes of some difficult cases. Reinhard Blumauer, from the Weltmuseum in Vienna, is

a Collection assistant and also provided valuable information regarding the attribution of the origin of mummies.

2.4 Imaging techniques

Most of these imaging methods were taught to me by the respective supervisors as part of the practical work on the Master's thesis. As far as possible, these techniques were then applied independently.

2.4.1 Background to micro-Computed Tomography and conventional Computed Tomography

Using computed tomography, it was possible to examine even those skulls that were still wrapped in organic or inorganic material without any destructive intervention. In addition, some examinations could be investigated in more detail (compared to the already skeletonized skulls) because measurements are not limited to the external anatomy.

Some important differences between these methods make μ -CT a more advantageous method than the conventional/medical CT (du Plessis et al., 2017): higher resolution, since the object and not the equipment rotates and more flexibility in setups such as voltage allow better imaging of materials with different densities

For these procedures, the corresponding supervisors have made the appropriate settings to achieve the optimal resolution. To make the scans repeatable, the settings used for each skull are provided in the following subchapters.

2.4.2 Micro-Computed Tomography (μ -CT) procedure

For this purpose, only the following four mummy skulls were selected, which had not yet been scanned by conventional CT at the VetMed (see next subchapter "Computed Tomography") and were in a very good state of preservation:

Mummified skulls 2876, 5877, 14726 and 15378 were scanned at the Vienna micro-CT Lab (University of Vienna, Department of Anthropology) with the Viscom X8060 NDT μ -CT scanner, under supervision of Univ.-Prof. Dr. Gerhard Weber and Mag. Martin Dockner

(Figure 12). The parameters, that were used for all four individuals are summarized in Table 6 (highlighted in green).

There was already a CT scan of the "The Clay Face" (inventory number 5) with the arbitrary inventory number 5 taken at the University of Veterinary Medicine Vienna. The scan had a rather low resolution of about only 500 μm (see next subchapter) and therefore not all analyses could be conducted based on the 3D imaging. However, because this skull represents a special case as there is no information about the origin of this skull in the inventory book and it was intended to obtain more detailed information from a high-resolution scan, the skull was scanned again. This time this was carried out at the Natural History Museum (NHM) in Vienna using the YXLON FF35 $\mu\text{-CT}$, under supervision of Dr. Wencke Wegner and MSc Viola Winkler (Figure 13). Additionally, the mummified head 2478 was also scanned at the Natural History Museum. The scan parameters, that were used for both individuals are summarized in Table 6 (highlighted in yellow).

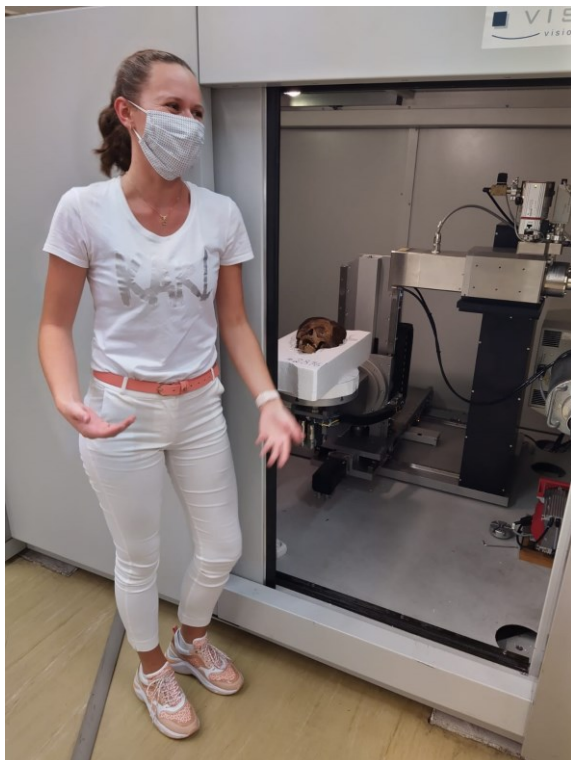


Figure 12. Working picture of the preparations for the $\mu\text{-CT}$ scans at the Vienna micro-CT Lab.



Figure 13. Working pictures of the preparation for the μ -CT scan at the Natural History Museum in Vienna.

2.4.3 Conventional Computed Tomography (CT) procedure

Three mummified heads with the inventory numbers 5043, 9200 and the individual given number 5 were scanned at the Imaging Diagnostics VetMed Vienna (University of Veterinary Medicine Vienna) with the SIEMENS CT VA0 COAD scanner in 2019, by Ella Fischer, an intern of the Natural History Museum in Vienna (Figure 14), under supervision of Josef Nekham and Bibiane Pollak. The scan parameters, that were used on the three individuals are summarized in Table 6 (highlighted in blue).

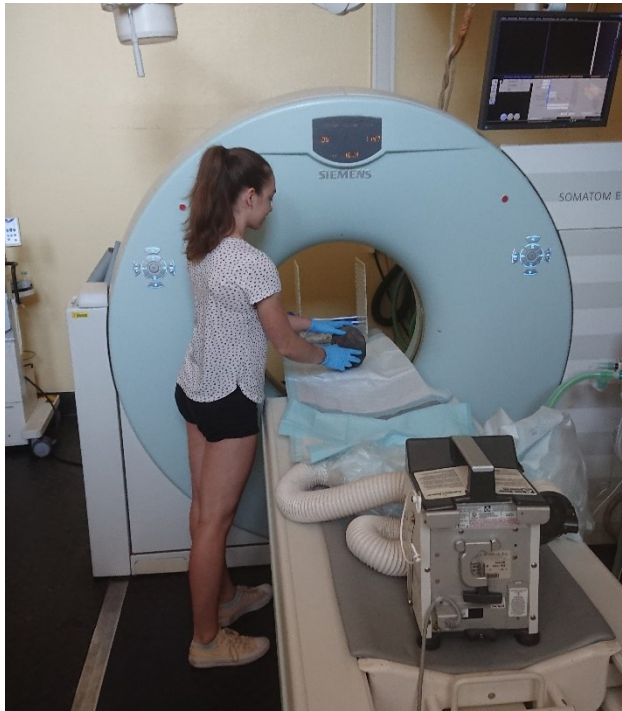


Figure 14. Picture of Ella Fischer scanning the mummied heads at the University of Veterinary Medicine in Vienna (Photo by Bernhard Weinzingner).

Table 6. Overview of the scanned individuals with the associated scan parameters.

Inv. numbers	2876	5877	14726	15378	5	2478	5043	9200	5
CT/μ-CT Institute	Vienna μ-CT Lab				NHM of Vienna		Vetmeduni Vienna		
Resolution	150 μm				97 μm	89 μm	500 μm		
Tube voltage	130 kV				120 kV		110 kV		130 kV
X-ray tube	330 μA				110 μA	130 mA	144 mA		
Exposure time	1400 ms				499,968 ms		1000 ms		
Cooper filter	0,75 mm				1,0 mm		?		
Magnification factor	0,5	0,33	0,33	0,33	1,55	1,69	1,76		
Number of scans	1147	1049	1067	1121	2860	2970	459	495	554

2.4.4 Background and procedure of surface scanning

According to Kersten et al. (2018), 3D scanning systems are increasingly used for a wide range of applications due to their high flexibility, portability and efficiency. Furthermore surface scanning is a non-invasive method to capture shape, texture and volume information, with an accuracy similar to a micro-Computed Tomography (Schäfer, n.d.).

In the case of this study, surface scanners are used to capture the morphology, the individual's anatomy and color information. Therefore, the handheld scanner was moved around the mummified heads until all angles were captured.

For this analysis, only mummified heads were scanned, because the aim was to capture their color and surface structure. The following inventory numbers were scanned with the structured light scanner Artec Leo: 5, 5877, 9200, 14726, 15378. For these mummified heads, the Artec Leo scanner, with the lower resolution was used, as all these mummies are almost completely wrapped and have therefore a rather smooth structures on the outer surface. Artec Leo has an accuracy of 100 μm , a resolution of 200 μm and a 3D-reconstruction rate of 80 frames per second. Because the two mummified heads with the inventory numbers 2478 and 5043 have an uneven, shiny surface and also finer structures than all others, the Artec Spider scanner, which results in higher resolution scans, was used. This scanner has an accuracy of 50 μm , a resolution of 100 μm and a speed of capture of 8 frames per second at maximum.

Two mummy heads were not scanned: The mummified head with inventory number 28 was not scanned because it is very fragmented. Mummified head 2876 s has much hair which would not be accurately captured by the surface scanner and excessive handling of this head would detach the hair.

2.4.5 Background and procedure of image processing

For further analysis and visualization of the μ -CT and CT scans the software Dragonfly 2021.3 from Object Research Systems (ORS) was used to reconstruct and visualize the wrapped mummy skulls, the bone and the internal skull structures. Reconstruction

settings used for mummy scans included window leveling to get a well visualized 3D image. Different color gradients were used to make different regions more visible. Using the clip box module allows sectional views in the 3D view and thus to look inside the objects.

Data processing of the surface scans, scanned with Artec Leo and Artec Spider, was carried out using the software Artec Studio 16. With this software it was possible to erase auxiliary surfaces, large outliers and noise and to align and fuse the multiple scans and to generate one 3D object. To optimize the frame position across all scans, global registration was used. With the defeature brush editor outliers and poorly scanned regions can be fixed. Finally, the texture information is applied to the object. What is left is a 3D object that represents the surface properties of the original object and contains the actual color information.

2.4.6 Background and procedure of x-ray imaging

Only in one case it was necessary to take an X-ray: it was taken of skull 2781 for fracture diagnosis. The x-ray image was obtained in a closed cabinet system with an GIERTH HF200A+ Gen 2 and the skull was placed on a flat panel detector Varex XRpad2 with the trepanation hole (see chapter 2.9.2) facing the detector plate (Figure 15). For better imaging a 1mm thick copper plate was placed between the detector and the skull and the settings were set to 64 kV and 3500 μ As.

This X-ray unit offers simple operation, with the X-ray pulse controllable by a hand trigger and the images are transferred directly to the computer, where they were saved as a .tif file.



Figure 15. Working pictures of the preparation for the x-ray imaging at the Natural History Museum, Department of Anthropology in Vienna.

2.5 Preservation status

The state of preservation of the skeletonized skulls and the mummified heads was determined by using the record sheet of the Human state Museum from McClelland (2012). Every bone of the skull, as well as single prominent areas were examined (for example the temporomandibular joint), where possible. A distinction was made between right and left, and the following classification was used: Bone is missing, 1-25% present, 26-75% present, 76-99% present and completely present (Table 7).

Table 7. Classification used for determination of cranial preservation (McClelland, 2012).

Cranial preservation classification	
missing	
1-25% present	
26-75%present	
76-100%present	
Completely present	

2.6 Age at death estimation

Age at death was determined for each skeletonized mummy head, or skull using the ectocranial suture closure according to Meindl & Lovejoy (1985). Both lateral-anterior and vault sites were observed and classified on a scale from 0 to 3. “0” means completely open sutures, “1” for minimal closure, “2” for significant closure and the score “3” was entered if the sutures showed already completely obliteration. The following sutures were scored for the vault system: midlambdoid, lambda, obelion, anterior sagittal, bregma, midcoronal and perion (Figure 1). For the lateral-anterior system the midcoronal, pterion, sphenofrontal, inferior sphenotemporal and superior sphenotemporal sutures were scored (Figure 16).

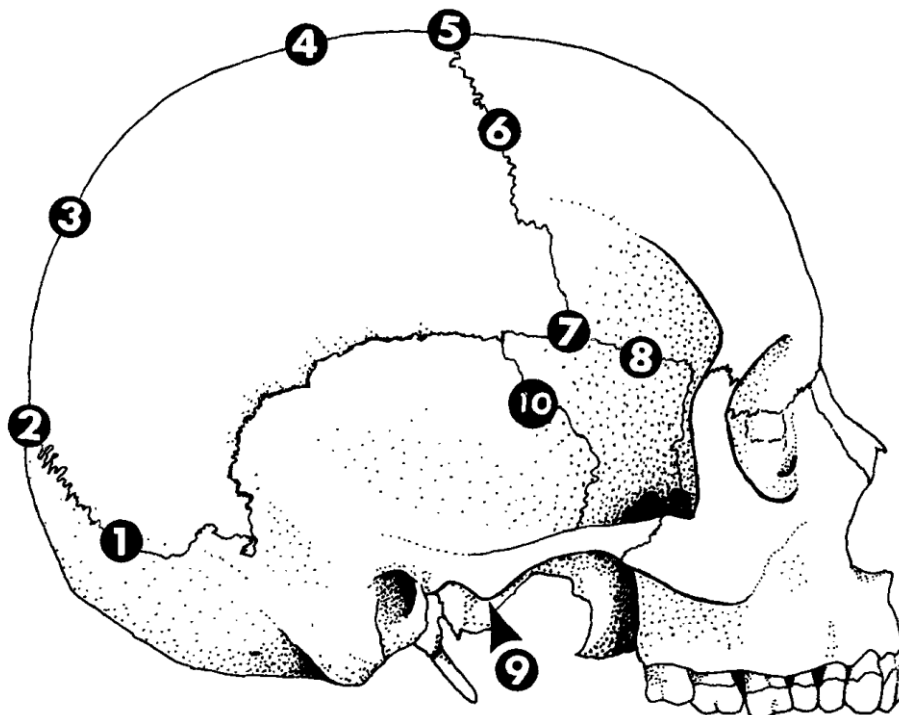


Figure 16. Ten observation sites for vault and lateral-anterior suture closure:

(1) midlambdoid, (2) lambda, (3) obelion, (4) anterior sagittal, (5) bregma, (6) midcoronal (7) perion (8) sphenofrontal, (9) inferior sphenotemporal and (10) superior sphenotemporal (Meindl & Lovejoy, 1985).

On bilateral suture sites, where closures were in different phases, scores were averaged for further calculations. For each system the points are summed up. Thus, the vault score, based on seven sutures, ranges from 0 to 21 and the five sutures of the lateral-anterior

score range from 0 to 15. Each sum of scores can then be assigned to a mean age at death (Table 8 & Table 9)

Table 8. Estimation of age at death in years based on ectocranial vault suture closure (Meindl & Lovejoy, 1985).

Age at death estimation: Vault sutures	
Composite Score	Mean Age at death (years)
1 - 2	30,5 ± 9,6
3 - 6	34,7 ± 7,8
7 - 11	39,4 ± 9,1
12 - 15	45,2 ± 12,6
16 - 18	48,8 ± 10,5
19 - 20	51,5 ± 12,6

Table 9. Estimation of age at death in years based on ectocranial lateral-anterior suture closure (Meindl & Lovejoy, 1985).

Age at death estimation: Lateral – anterior sutures	
Composite Score	Mean Age at death
1	32,0 ± 8,3
2	36,2 ± 6,2
3 - 5	41,1 ± 10,0
6	43,4 ± 10,7
7 - 8	45,5 ± 8,9
9 - 10	51,9 ± 12,5
11 - 14	56,2 ± 8,5

According to Buikstra & Ubelaker (1994) the result from the mean age at death of the vault and lateral-anterior sutures can then be classified in one of the following categories: young adult, middle adult or old adult (Table 10).

Table 10. Classification of the overall assessment into one of the three age groups (Buikstra & Ubelaker, 1994).

Age group	
Child	5 – 12 years
Adolescent	12 – 20 years
Young adult	20 – 34 years
Middle adult	35 – 49 years
Old adult	50+ years

For very young individuals, or if the results for the vault sutures and lateral-anterior sutures differed so that a clear classification into one of the age groups was not possible, tooth abrasion and/or joint abrasion of the mandible and maxilla and of the occipital condyles were also included in the age classification (Buikstra & Ubelaker, 1994).

For subadult individuals, with at least the third molar not yet fully developed, an age at death estimation according to AlQahtani et al. (2010) was made on the basis of a tooth eruption scheme. The author has graphically classified developmental stages by defining certain distinguishing features, correlating to the specimens age (Figure 18). In addition, the root developmental stage was used for age at death estimation, when a not fully developed tooth root was well visible (Figure 17). Therefore, AlQhatani provides a table that allows classifying teeth into age groups, for combined sexes but with a distinction between mandible and maxilla. Male tooth eruption development is slightly slower than it is among females. However, since this difference is no more than one developmental stage in AlQahtani's scheme, no differentiation was made between males and females (AlQahtani et al., 2010). All ages given by Alqhatani et al. (2010) in this paper represent the midpoint of one age year.

The subadult individuals were also assigned to the appropriate age group, child or adolescent (Table 10), according to Buikstra & Ubelaker (1994).

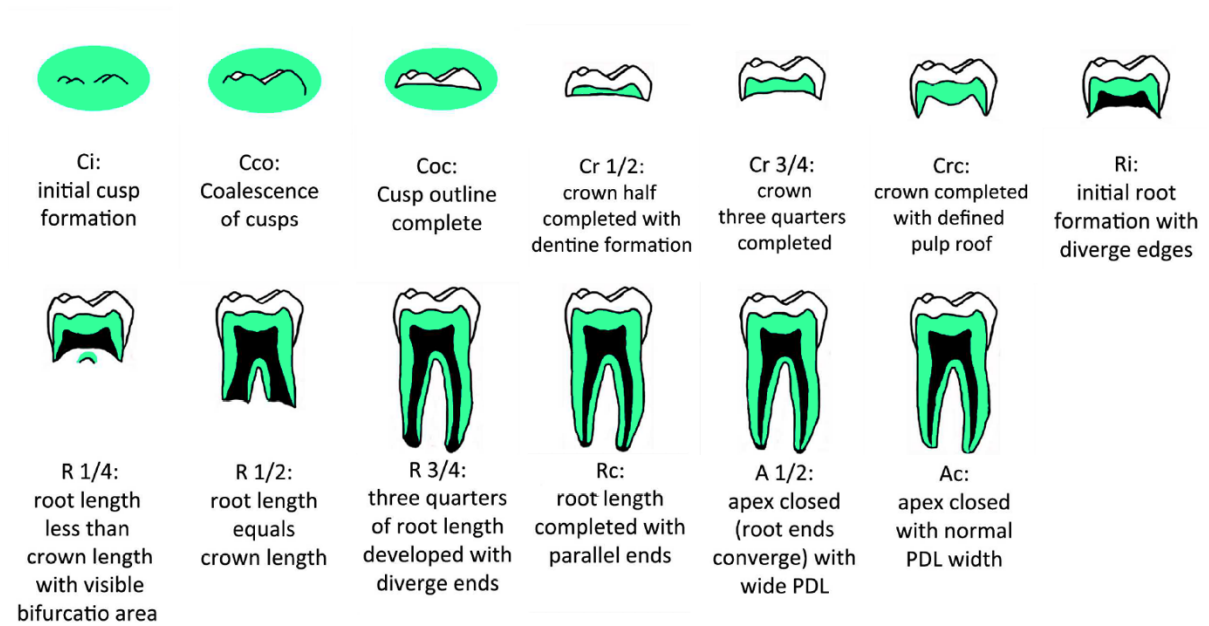


Figure 17. Developmental stages of multirooted teeth according to AlQahtani et al. (2010).
[Figure adapted with GIMP-2.10]

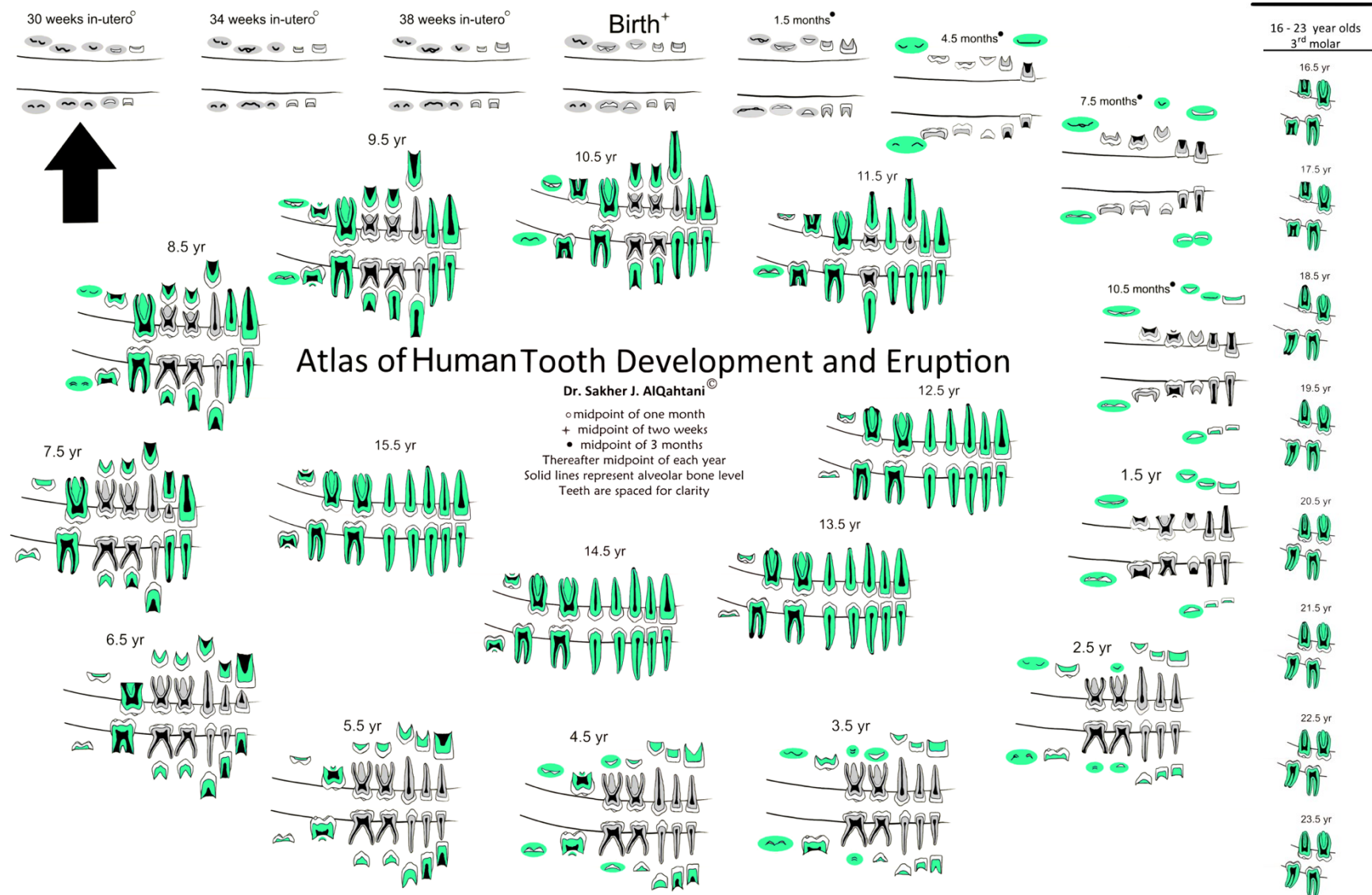


Figure 18. Atlas of human tooth development and eruption according to AlQahtani et al. (2010).

This scheme was used to classify the whole dentition into one of these age groups to reach a general age at death estimation. [Figure adapted with GIMP-2.10]

2.7 Sex estimation

In bioarcheology there is a distinction between sex and gender. Sex is biological and the classification is based on reproductive organs and gametes, resulting in two categories of sex: male and female. In contrast, the term gender is associated with social roles and construct and therefore is not biologically determined, nor can it be estimated straightforward from the skeletal remains. While biological sex can be clearly assigned in most cases, gender identity does not always match expectations associated with assigned biological sex and can be considered as a nonbinary construct (Klales, 2020).

According to Pickering & Bachman (2009) and many other scholars the pelvis provides the most accurate results for sex estimation. But fortunately, there are also other sexual characteristics on the human skeleton, because the pelvis is not always preserved, and in the present study is completely absent for all cases analyzed. The second best reliable sex indicator are the features on the skull (Pickering & Bachman, 2009). For this study, skull features were used for sex estimation, as no other skeletal remains were available.

When estimating sex, certain morphological features are more frequently observed in certain groups of people (Caple & Stephan, 2017). Consequently, the skulls were first grouped according to the origin attributed to each of them by the time they reached the Museum. This means that if the inventory book indicated that this was an Egyptian mummy, then that was assumed to be the case. Then the skulls were sorted according to robustness from feminine/gracile to masculine/robust. Finally, sex was estimated among those individuals originally assigned to Peru and independently for those assigned to Africa, since these were the broad groups of origin of those studied herein.

The inventory book provided the rough origin of the skulls for all individuals except for the mummified head with inventory number 9200 and number 5 "The Clay Face". For these two, sex was estimated according to the degree of expression of cranial markers without assigning them to a place of origin, leading to a less reliable estimation.

The sex estimation is based on the model of Ferembach et al. (1979). For this purpose, 11 characteristics on the skull and four characteristics on the mandible were classified into five categories: +2 (hyperfeminin), +1 (feminin), 0 (intermediate), -1 (masculine), -2

(hypermasculine) (Table 11). After the assessment of the level of expression, the individual characteristics were multiplied by their specified weighting factors, which varies between one and three, depending on the reliability of the sex-determining characteristics. The sum of the products is then divided by the total sum of the weightings. This results in a score between -2 and +2 for each individual, which allows a classification into the two categories "male" or "female". If the score is around zero, no secure classification into one of the two sexes can be made.

For three skulls, the sex score range between ± 0.5 and ± 0.2 ; in these cases the individual was described as “probably” female or “probably” male.

Table 11. Sex estimation characteristics at the human skull according to Ferembach et al. (1979).

Sex estimation characteristics at the skull						
		Hyper-feminin	Feminin	Intermediate	Masculine	Hyper-masculine
Cranium	Weight	-2	-1	0	1	2
Glabella	3	smooth	slightly delimited	delimited	marked	massive, prominent
Superciliary arches	2	smooth	slightly delimited	delimited	marked	very marked
Frontal and parietal eminences	2	marked	medium	moderate	indistinct	missing
Frontal profile	1	vertical	almost vertical	little inclined	medium inclined	strongly inclined
Mastoid process	3	very small	small	medium	large	very large
Nuchal crest	3	missing	slightly arched	evident	marked	rough surface
External occipital protuberance	2	smooth	hardly	medium	marked	very marked
Zygomatic process of temporal bone	3	very thin and low	thin and low	medium	thick and high	very thick and high
Zygomatics	2	very low, smooth surface, thin	low, smooth surface, thin	medium, irregular surface	high, irregular surface	very high, irregular surface
Supramastoid crest	2	smooth	hardly	medium	marked	very marked
Orbital form	1	very round, sharp border	round, sharp border	transitory form, medium border	quadrangular, rounded border	very quadrangular, rounded border
Mandible						
General impression	3	gracile	slightly gracile	medium	robust	very robust
Mental tubercle	2	small, round	small	medium	thick	very thick
Angle of mandible	2	smooth	hardly	delimited	marked	rough surface
Inf. edge of mandible	1	thin	thin	medium	thick	thick

2.8 Dental status

Teeth can provide information about a person's interaction with the environment, through issues like chewing, dental wear, and trauma. Furthermore, teeth are highly mineralized making them the densest body substance and are therefore very resistant against taphonomic processes. Dental diseases are related to diet, oral pain and dental tooth loss (Ogden, 2007).

2.8.1 Dental inventory

A tooth status was applied individually to each tooth, according to a record sheet created for the deciduous and the adult dentition by McClelland (2012) (Table 13 & Table 14).

The Fédération Dentaire Internationale (FDI) numbering system according to Leatherman (1972) as well as the Standards from Buikstra & Ubelaker (1994) were used and some additional categories were adapted from Brickley et al. (2004).

Table 12 provides a summary of the coding system. Categories “1” and “2” describe a tooth that is fully present but may not be fully developed. Categories “3” to “6” describe the alveolar tissue that shows a missing tooth. Category “8” should be used when a tooth is unobservable, as in the case of an erupting tooth of the deciduous dentition or a permanent tooth in crypt. Instead of category “7”, the letter “b” was used to describe a broken tooth (Brickley et al., 2004). If only the jaw bone or jaw and the corresponding tooth were missing, then the signs “-” and “-” after Brickley et al. (2004) were used.

Table 12. Coding for the dental inventory categories according to Brickley et al. (2004) and Buikstra & Ubelaker (1994).

Dental inventory categories	
Coding	Definition
1	Tooth is present, but not in occlusion
2	Tooth is present, development completed, reached occlusal surface
3	No associated alveolar bone
4	Premortem tooth loss
5	Postmortem tooth loss
6	Congenital absence
8	Tooth is unobservable
b	Tooth is partly broken
-	Tooth is present, but socket is missing
---	Jaw bone and tooth are missing

Table 13 Recording sheet for the dental inventory of a deciduous dentition (McClelland, 2012).

Deciduous teeth										
	Upper right					Upper left				
Calculus										
Abscesses										
Caries										
Abrasion										
Inventory										
	55	54	53	52	51	61	62	63	64	65
	M ²	M ¹	C	I ²	I ¹	I ¹	I ²	C	M ¹	M ²
	M ₂	M ₁	C	I ₂	I ₁	I ₁	I ₂	C	M ₁	M ₂
	85	84	83	82	81	71	72	73	74	75
Inventory										
Abrasion										
Caries										
Abscesses										
Calculus										
	Lower right					Lower left				

Table 14 Recording sheet for the dental inventory of a permanent dentition (McClelland, 2012)

Permanent teeth																
Upper right								Upper left								
Calculus																
Abscesses																
Caries																
Abrasion																
Inventory																
	18	17	16	15	14	13	12	11	21	22	23	24	25	26	27	28
	M ³	M ²	M ¹	P ⁴	P ³	C	I ²	I ¹	I ¹	I ²	C	P ³	P ⁴	M ¹	M ²	M ³
	M ₃	M ₂	M ₁	P ₄	P ₃	C	I ₂	I ₁	I ₁	I ₂	C	P ₃	P ₄	M ₁	M ₂	M ₃
	48	47	46	45	44	43	42	41	31	32	33	34	35	36	37	38
Inventory																
Abrasion																
Caries																
Abscesses																
Calculus																
Lower right								Lower left								

2.8.2 Dental caries

For recording caries, Buikstra & Ubelaker (1994), was used. Categories numbered from 1 to 6 are summarized in Table 15: “1” describes caries at **occlusal surfaces** including those involving grooves, pits, cusps, dentin exposures and the buccal and lingual grooves of the molars; “2” includes caries at **interproximal surfaces** with mesial and distal cervical regions; the score “3” was used for caries on **smooth surfaces** such as the buccal (labial) and lingual surfaces (other than grooves); “4” describes **cervical caries** that occur at any point of the cemento-enamel junction and do not belong to the interproximal region; “5” describes **root caries** below the cemento-enamel junction; **large caries**, that destroyed so much of the tooth that they cannot be assigned a surface of origin are numbered with “6”.

Table 15. Coding for recording caries (Buikstra & Ubelaker, 1994).

Dental caries	
Coding	Definition
1	Caries at the occlusal surface
2	Caries at the interproximal surfaces
3	Caries on smooth surfaces
4	Cervical caries
5	Root caries
6	Large caries

2.8.3 Abscesses

Abscess observation is based on Buikstra & Ubelaker (1994). A **buccal or labial abscess** presence was recorded with “1” and an **abscess perforation on the lingual side** was scored as “2”.

2.8.4 Calculus

Dental Calculus was reported according to Brothwell (1981). The numbers provide information about the size and degree of severity of the calculus (Figure 19): “1” indicates a small amount, “2” moderate amount and “3” for large amount of calculus. The location of the calculus was described with lowercases: “m” = mesial, “b” = buccal/labial, “d” = distal, “l” = lingual.

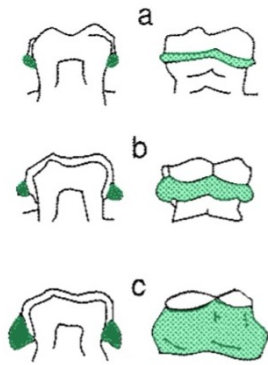


Figure 19. Picture from the Standards (Buikstra & Ubelaker, 1994; edited with Adobe Fresco 2.7.9. by Liesa Geppner) shows the three different levels of expression for calculus according to Brothwell (1981).

2.8.5 Dental Abrasion

For the analysis of the degree of dental abrasion the criteria developed by Lovejoy (1985) were used. Lovejoy describes each tooth in each phase and also gives a graphic description that can be used to assign the teeth to a certain phase very well. Figure 20 and Figure 21 show the graphic description of the dental abrasion.

Based on this, the degree of abrasion was then divided into three categories: slight (s), medium (m) and high (h) abrasion. Table 16 shows which degree of abrasion can be assigned to which category. Those tooth abrasions were indicated as not observable (n.d.) when it was not possible to identify the degree of tooth abrasion due to the low resolution of the CT scans. Not determinable (n.d.) refers to those individuals for which the abrasion degree could not be determined, either because they had a deciduous dentition or because all teeth were missing.

Table 16. Abrasion categories, classified according to the abrasion degree.

Abrasion category	
Coding	Definition
s	Abrasion degree between A and C
m	Abrasion degree between D and F
h	Abrasion degree between G and H

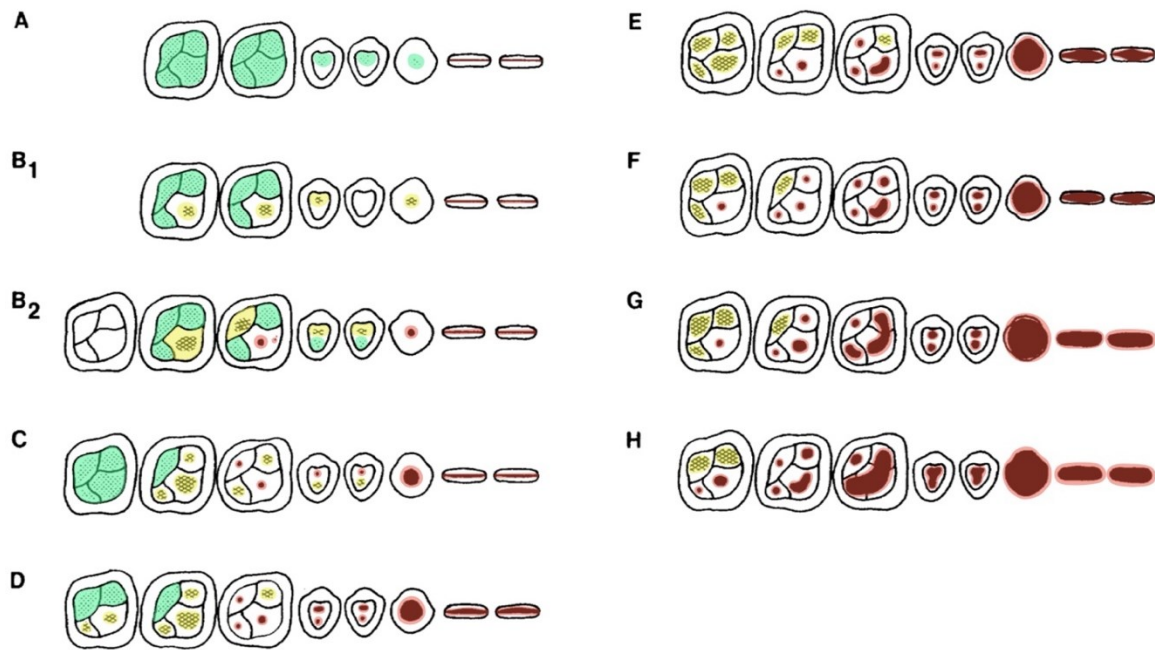


Figure 20. Picture of the different stages of abrasion degrees of the maxillary dentition according to Lovejoy (1985; edited with Adobe Fresco 2.7.9. by Liesa Geppner).
The green highlight means, that no dentin is exposed and only slightly polished dental surface is visible. The yellow highlight means that no dentin is exposed but wear facets are visible. The extent of the exposed dentin is highlighted in red. If no significant dental wear is visible, the tooth was left in white.

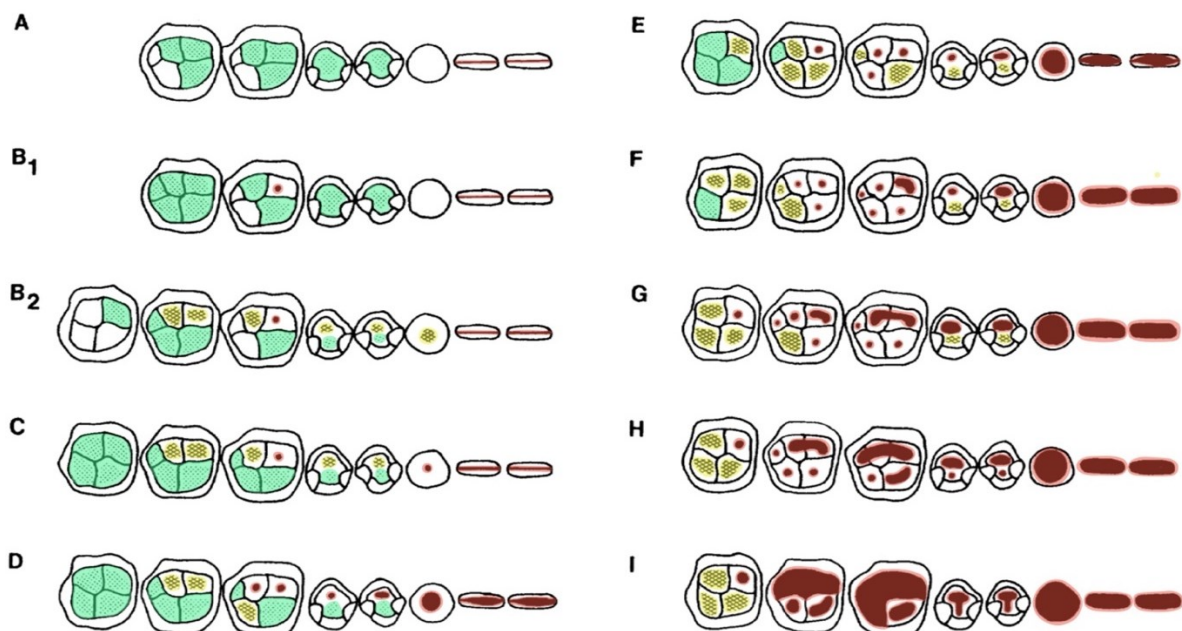


Figure 21. Picture of the different stages of abrasion degrees of the mandibular dentition according to Lovejoy (1985; edited with Adobe Fresco 2.7.9. by Liesa Geppner).
The green highlight means, that no dentin is exposed and only slightly polished dental surface is visible. The yellow highlight means that no dentin is exposed but wear facets are visible. The extent of the exposed dentin is highlighted in red. If no significant dental wear is visible, the tooth was left in white.

2.9 Modification of the living

2.9.1 Intentional cranial modification

Intentional cranial modification is a cultural practice, where the cranial shape of infants has been altered (Okumura, 2014). This has led to the appearance of different deformation techniques on the neurocranium in different time periods and cultures (Vyslozil, 2000).

Table 17 shows the recording sheet for intentional cranial modification with their specific characteristics, according to Buikstra & Ubelaker (1994). Based on these characteristics, the expression of intentional cranial modification was described.

The general category makes a distinction between a *tabular* or a *circumferential* modification. The following forms of modifications were distinguished: the *lambdoid* deformation describes a posterior deformation at the lambda region. If there is a posterior deformation, perpendicular to the transverse plane, it is called *occipital* deformation. A deformation at both the frontal and occipital bone is called a *fronto-occipital* deformation. The *loaf-shaped* deformation describes the appearance of an annular wrapped skull (Figure 22).

In order to compare the presence and type of intentional cranial modification across the individuals studied herein, the presence or absence of different elevations or depressions of the cranial vault was answered with *yes* or *no*.

The two questions for posterior and anterior aspects (Intentional cranial modification present?; Impression of binding visible?) can also be answered with *yes* or *no*. There are three different degrees of deformation: *mild*, *moderate* or *extreme*. For the question: "Symmetrical reshaping?" there are the following answer options: *yes*; *no, right side is more deformed* or *no, left side is more deformed*. For the posterior aspect, the pressure can be placed at the *lambda*, at the *squamous portion of occipital* or *below the inion*. For the anterior aspect, the choices for the location of the pressure are: *high near the coronal suture* or *low near or below the frontal boss*. The plane of pressure in relationship to the transverse plane can be perpendicular (90°) or obtuse (>90°). The pad

location can be located on the *midline, symmetrically lateral to the midline, asymmetrically left or asymmetrically right.*

Table 17. Recording sheet for intentional cranial modification according to Buikstra & Ubelaker (1994).

Intentional cranial modification
General aspects
General category
Form
Elevation at bregma
Elevation at lambda
Post-coronal depression
Depression at lambda
Sagittal elevation
Posterior aspects
Cranial deformation present?
Degree of deformation
Symmetrical reshaping?
Pressure was centered at
Plane of pressure in relationship to transverse plane
Pad location
Impression of bindings visible?
Anterior aspects
Cranial deformation present?
Degree of deformation
Symmetrical reshaping?
Pressure was centered at
Pad location
Impression of binding visible?

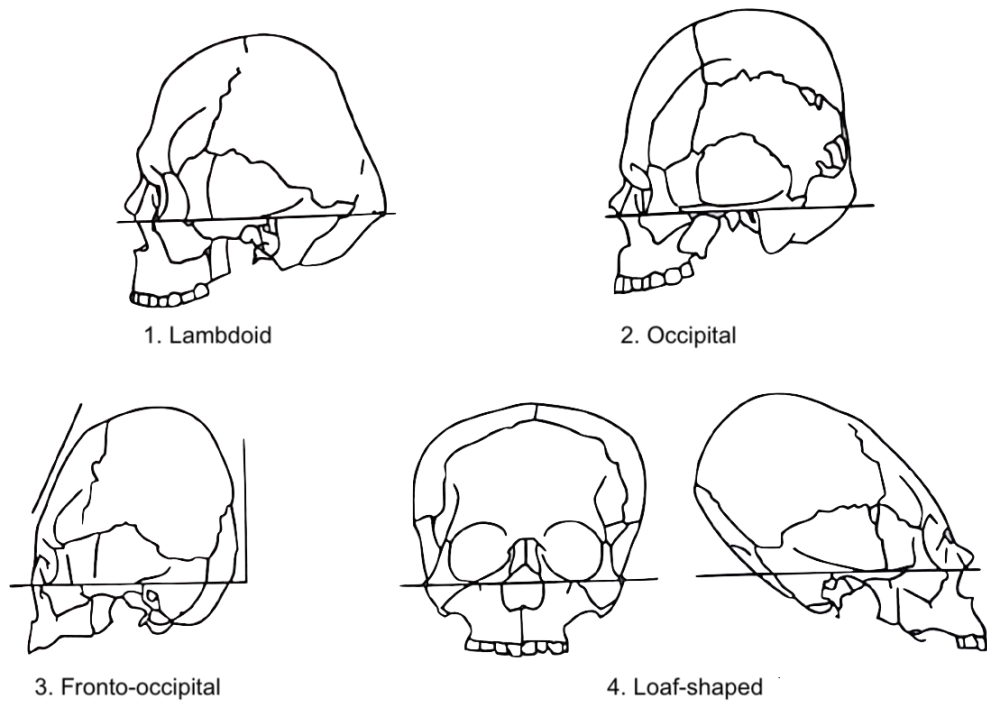


Figure 22. Different forms of intentional cranial modification according to Buikstra & Ubelaker (1994).
 1. – 3. shows three different types of tabular intentional cranial modification and number 4 shows a type of circumferential intentional cranial modification.

2.9.2 Trepanation

Trepanation is the willful operation on the neurocranium, which can be performed using various methods and different tools. The main reason for performing trepanation in the past was the treatment of head injuries (Kushner et al., 2018).

Trepanation is described according to the recording form from Buikstra & Ubelaker (1994). The coding for Trepanation is based on the following characteristics (Table 18): the location of the trepanation, certainty of identification (possible or clear evidence of trepanation), technique used to open the cranial bone (scraping, grooving, drilling and cutting, form of the incision (circular or rectangular), evidence of healing (no, possible or definite evidence of healing) and details of the dimensions of the trepanned area.

Table 18. Recording sheet for trepanation according to Buikstra & Ubelaker (1994).

Trepanation
Location: Bone
Location: Site
Certainty
Technique
Healing
max. Dimension (mm)
min. Dimension (mm)

2.10 Palaeopathology

The skeletonized skulls and mummified heads were also examined for palaeopathological changes. These include disease-related bone changes, as well as traumata. Obviously, the mummified heads most often did not allow direct visual inspection of the bone surface, that is why X-ray and CT-scans were performed.

Cribra orbitalia and porotic hyperostosis was assessed according to the classification system of Rinaldo et al. (2019). This includes a detailed description of the degree of severity and degree of healing scales and the size of the affected area (Table 19). Both palaeopathologies are porous bone lesions, that appears on the outer surface of the orbits (cribra orbitalia) or the cranial vault (porotic hyperostosis) (Rinaldo et al., 2019).

In the case of traumata, a distinction between peri- and postmortem fracture was made. Ribeiro et al. (2020) gives a traits distribution of perimortem and postmortem fractures. For this study perimortem cranial fractures were compared to experimentally produced cranial fractures of dry human crania (Ribeiro et al., 2020). The results present nine traits that can be associated with fresh cranial fractures. Statistical analyses shows that some of the traits that could be associated with fresh cranial fractures are distinctly related to perimortem/ fresh bone conditions. This includes undulated margins, which occur exclusively in perimortem fractures as well as flake defects and crushed margins. Postmortem fractures, on the other hand, shows irregular and random pattern.

Further palaeopathological changes found in the examined skulls were described by their appearance following Buikstra & Ubelaker (1995). This included systematic evaluations of external auditory canal exostosis, lipping on the temporomandibular joint and the occipital condyles and traumata. External auditory exostosis is a disease in which new bone formation occurs in the external auditory canal (Rhys Evans & Cameron, 2017). Osteoarthritis is a disease of the movable joints characterized by abrasion and degeneration of the articular cartilage as well as new bone formation on the joint surface (occipital condyles, mandibular fossa of the temporal bone) and involvement of the subchondral bone (mandibular condyle) (Dequeker & Luyten, 2008).

Table 19. Description of degree of severity and healing for describing cribra orbitalia and porotic hyperostosis according to Rinaldo et al. (2019).

Feature	Degree of Expression	Description
Severity	0	Absence of lesions
	1	Presence of small, scattered holes
	2	Presence of small and large scattered holes
	3	Presence of holes that join within the trabecular structure
	4	Marked development of the trabecular part of the bone surface, which protrudes toward the outside
Healing	1	No healing activity: all holes are un-remodelled with sharp margins
	2	Healed area < 50%: holes have rounded margins or are already completely closed
	3	Healed area > 50%: holes have rounded margins or are already completely closed
	4	Fully healed lesions

2.11 Taphonomy

From the time of death until their analysis for the present work, bones undergo a variety of changes, which can be referred to as taphonomy. The study of the most important taphonomic changes at the skulls are briefly described below and refer to the literature of Behrensmeyer (1978), Buikstra & Ubelaker (1994) and Pokines & Symes (2014).

2.11.1 Bone color

The bony skull surface was assigned to a color. The corresponding possible reason for this color is listed in Table 20 (Pokines & Symes, 2014).

Table 20. Taphonomic processes and associated bone color according to Pokines & Symes (2014).

Associated color	Taphonomic process
Yellow to brown	Normal fresh bone devoid of flesh
Ivory	Due to desiccation the bones become dry during the postmortem period and the yellowish hue can change to ivory or off-white color
Yellow to bright white	Commercial preparation
Tan to dark brown	Industrial chemicals: based on exposure of hydrochloric acid (HCl); occur at temperature as low as 200-300 degrees centigrade
White	Sun bleaching; exposure to sodium hydroxide (NaOH); adipocere remnants; burning; adhered concretions and commercial preparation of skeletal remains for teaching
Grey	Sun bleaching; at 800 degree centigrade: calcined white to blue-grey coloration

2.11.2 Staining

Besides the basic bone color, there is often additional staining, which can have a wide variety of causes (Pokines & Symes, 2014). The ones chosen to describe the skulls and heads analyzed herein are listed in Table 21 below.

Table 21. Taphonomic process and associated staining color according to Pokines & Symes (2014).

Staining color	Taphonomic process
Dark reddish brown	Hemolysis
Orange, red, brown, black	Iron
Green to bluish-green	Copper and copper alloys
Grey, silver to black	Mercury
Green	Algae, Mosses
Light brown to black	Roots and decomposing plant materials

2.11.3 Bone weathering

If the bone is exposed at the soil surface and exposed to certain temperatures and humidity, weathering of the bone occurs. The first signs are superficial cracks and in the final stage of weathering the bone falls apart with large splinters. Table 22 shows the different weathering stages with descriptions, which were used to determine the bone weathering on each skull (Behrensmeyer, 1978).

Table 22. Six different bone weathering stages according to Behrensmeyer (1978).

Weathering stage	Description
Stage 0	No signs of cracking or flaking
Stage 1	Little cracking, parallel to the fiber structures
Stage 2	Outermost, thin bone layers show flaking; still attached to the bone; crack edges are angular in cross section
Stage 3	Patches of rough, homogeneously weathered compact bone; not deeper than 1,0-1,5mm; crack edges are rounded in cross section
Stage 4	Bone surface is coarsely fibrous and rough; large and small splinters; weathering penetrates inner cavities; cracks are open with splintered or rounded edges
Stage 5	Bone falls apart; cancellous bone exposed

2.11.4 Surface damage

Surface damage on bone or mummified tissue was described by their location and appearance. This included cutmarks, evidence of rodent and carnivore gnawing, insect damage, plant root damage, contact erosion and burn marks (Buikstra & Ubelaker, 1994).

For burned bone parts, the locations where the bone is burned, the discoloration and the extent to which this affects the bone were indicated. The surface structure was also described in more detail: longitudinally split, longitudinal and transverse checking or curved cracks. Furthermore, information was recorded as to whether the bone was deformed by heat (Buikstra & Ubelaker, 1994).

2.11.5 Adherent materials/ Evidence of mummification

Regarding mummified heads, the material adhering to the bone and the mummification process was described. The skeletonized skulls are mostly only covered with small parts of soft tissue remains, while in the still mummified heads the entire wrapping material, including soft tissue, hair und bandages, is preserved and described.

2.11.6 Cultural modification of the death

The term cultural modification is used to describe those transformations that are performed shortly after death, to prepare the dead for “eternal peace”. These include, for example, excerebration for a better preservation of the skull, as well as ritual skull paintings (Pokines & Symes, 2014).

2.11.7 Curation modification

Modifications are often found on skulls to prepare the human remains for better storage or for further use (for example for exhibitions) (Pokines & Symes, 2014). This includes

small holes located on the mandible to fix it to the rest of the skull, glue residues and other adhesives to hold different parts of the skull together, writing of names or serial numbers and unintentional marks, and colored spots. Bone breakage, which is caused by repeated handling, was also recorded under curation modification.

2.11.8 Scientific use

The term scientific use is employed to describe all modifications to the skull or head that are related to scientific purposes. This includes places on the skull marked with a pencil to indicate measurement points or drilled holes to get samples for molecular/chemical analyses.

2.11.8.1 C¹⁴ Dating

Samples of four mummified heads were sent for dating to the Curt-Engelhorn-Zentrum Archäometrie gGmbH in Mannheim. Results were obtained from individuals with the following inventory numbers: 2875, 2876, 5043 and 14726. Bones and tissue material were taken for this purpose. From the bone collagen was extracted and ultrafiltration was used to separate the fraction above 30kD. The fraction was then freeze-dried. If tissue material is used for C¹⁴ analysis, the material was first cleaned from contamination or preservation with various organic solvents such as benzene or acetone, and then subjected to the ABA method (Acid/Base/Acid, HCl/NaOH/HCl). Afterwards, the remaining samples (from bone or tissues material) were burnt to carbon dioxide in an elemental analyzer and the carbon dioxide was catalytically reduced to graphite. The ¹⁴C content was measured with a MICADAS AMS system. The ¹⁴C/¹²C and ¹³C/¹²C isotope ratios of samples, calibration standards (oxalic acid II), blanks and control standards were measured simultaneously in the AMS. Further the determined ¹⁴C ages are calibrated to calendar ages (Lindauer, 2021).

3 Results

The aim of this work is to produce a comprehensive report on the mummies from the Natural History Museum in Vienna that have not been investigated until now. For this purpose, the work is divided into different chapters: Chapter 3.1 and 3.2 provide information on the provenance research and the associated collectors respectively. In chapter 3.3 a distribution of the skulls and mummified heads by origin, that is country of origin, is made. From chapter 3.5 onwards, those results are presented whose examinations were carried out directly on the skulls or heads. This includes an age at death and sex estimations, as well as analyses on dental health, intentional cranial modification, trauma and injuries, selected palaeopathological and taphonomical changes. Finally, Chapter 3.9 gives an overview of the different mummification techniques which were prevalent in the respective countries of origin and temporal periods.

3.1 Provenance research at the Department of Anthropology of the NHM

3.1.1 Provenance according to the Inventory book

Table 23 gives an overview of the entries of the individual skulls and heads in the inventory book. This already helps to clarify many uncertainties about the collectors and the circumstances in which the skulls and heads came to the museum. Twenty two of the 23 entries provide information about the origin and often there is also a short description of the object itself.

Table 23. Summary of the information provided by the inventory book for each skull or mummified head of the Department of Anthropology.
No information was obtained in the inventory book if described with “?”:

Inv. no.	Inventory book				Inventoried by			Entry in the inventory book		Today present as
	Name	Section	Date	Page	Name	Date	Page	German	English	
5	?	?	?	?	?	?	?	?	?	Mummified head
28	OSTE: no. 1 – 1470	Post B XVII	1877	18	Kittl and Hochstetter	1879	137	„Mumienschädel aus Ägypten. Geschenk von E. [Ernest] Marno. Mumienschädel von Medinet Tabû aus den alten Königsgräben von Theben, gegenüber von Luxor; Gesicht zerstört, Unterkiefer vorhanden.“	“Mummy skull from Egypt. Gift of E. [Ernest] Marno. Mummy skull from Medinet Tabû from the ancient royal tombs of Thebes, located opposite Luxor; face destroyed, mandible present.”	Mummified head
1523	OSTE: no. 1461 – 2894	Post III	1884	21	Szombathy	1884	22	„Deformierter Mumienschädel von Chancay in Peru. Calvarium eines Kindes. Nähte einfach, Mol. [Molar] 2 und I. [Incisivi] 1 und 2 zum Durchbrechen begriffen. Basooccipital fehlt.“	“Deformed mummy skull from Chancay, Peru. Calvary of a child. Simple sutures. Second molar and first and second incisor about to break through. Basooccipital bone missing.”	Skeletonized skull
1525	OSTE: no. 1461 – 2894	Post III	1884	21	Szombathy	1884	22	„Deformierter Mumienschädel von Ancon in Peru. Cranium eines Erwachsenen. Os Incae vollkommen ausgebildet. NB. [nota bene/ Anmerkung?] Der ethn. S. [ethnologischen Sammlung] zur Ausstellung geliehen, 21.4.1916.“	“Deformed mummy skull from Ancon, Peru. Cranium of an adult. Inca bone fully developed. NB. [note?] Lent to the ethnological collection for the exhibition, 21.4.1916.”	Skeletonized skull
1526	OSTE: no. 1461 – 2894	Post III	1884	22	Szombathy	1884	22	„Deformierter Mumienschädel von Gran Chimu in Peru. Cranium mit normalen Nähten in beginnender Obliteration. Nasalia in ihren oberen Teilen verwachsen. Die Molaren fehlen.“	“Deformed mummy skull from Gran Chimu, Peru. Cranium with normal sutures in beginning obliteration. Nasalia fused in its upper parts. The molars are missing.”	Skeletonized skull

Inv. no.	Inventory book				Inventoried by			Entry in the inventory book		Today present as
	Name	Section	Date	Page	Name	Date	Page	German	English	
2229	OSTE: no. 1461 – 2894	Post VI	1885	99	Szombathy	?	106	„Rassenschädel und -Becken, gesammelt von Herrn Dr. Augustin Weisbach. K.K. [kaiserlich königlicher] Stabsarzt, Direktor des österreichisch-ungarischen National-Spitals in Constantinopel. Geschenk des Herrn Salo Cohn in Wien, 1885. ♂[männlich], 20 - 25 Jahren (Mumie). Dolichocephalus mit offener Stirnnaht und vielen zierlichen Lambdazwickelbeinen. War einbalsamiert; hatte kurze braune Haare. Mit Unterkiefer. Aus Unterägypten. Cranium.“	“Racial skulls and pelvis collected by Dr. Augustin Weisbach. K.K. [Imperial Royal] staff Surgeon, Director of the Austro-Hungarian National Hospital in Constantinople. Present from Mr. Salo Cohn in Vienna, 1885. ♂[male], 20 - 25 years (mummy). Dolichocephalus with open frontal suture and many delicate lambda gusset legs. Was embalmed; had short brown hair. With lower jaw. From Lower Egypt. Cranium.”	Skeletonized skull
2231	OSTE: no. 1461 – 2894	Post VI	1885	99	Szombathy	?	106	„Rassenschädel und -Becken, gesammelt von Herrn Dr. Augustin Weisbach. K.K. [kaiserlich königlicher] Stabsarzt, Direktor des österreichisch-ungarischen National-Spitals in Constantinopel. Geschenk des Herrn Salo Cohn in Wien, 1885. ♂[männlich] in den 30er Jahren. Dolichocephalus. Scheiteldach ohne Hinterhaupt. Vom selben Platze wie 354 [bei Nr. 354 steht: von Damaskus (Syrien) wie Nr. 339]. Calvarium.“	“Racial skulls and pelvis collected by Dr. Augustin Weisbach. K.K. [Imperial Royal] staff Surgeon, Director of the Austro-Hungarian National Hospital in Constantinople. Present from Mr. Salo Cohn in Vienna, 1885. ♂[male] in his 30s. Dolichocephalus. Parietal roof without occiput. From the same place as 354[at no. 354 it is written: from Damascus (Syria) as no. 339] ¹ . Calvarium”	Skeletonized skull

¹ No additional useful information could be found when tracing this reference in the inventory book.

Inv. no.	Inventory book				Inventoried by			Entry in the inventory book		Today present as
	Name	Section	Date	Page	Name	Date	Page	German	English	
2478	OSTE: no. 1461 – 2894	Post XII	1885	137	Szombathy and Heinzel	1889	138	“Schädel aus dem Nachlass Sr. [seiner] kaiserlichen Hoheit des durchlautigsten Herrn Erzherzogs Kronprinz Rudolf. Ägyptische Mumie, aus Moabdah’s Höhle bei Manfalut.”	"Skull from the bequest of His Imperial Highness the Most Serene Lord Archduke Crown Prince Rudolf. Egyptian mummy, from Moabdah's cave near Manfalut."	Mummified head
2859	OSTE: no. 1461 – 2894	Post XIX	?	197	Szombathy and Heinzel	1890	201	„Mumienschädel von Luxor, Oberägypten, Dedikation Dr. Leuthner.“	„Mummy skull from Luxor, Upper Egypt, dedication Dr. Leuthner.“	Skeletonized skull
2871	OSTE: no. 1461 – 2894	Post XIX	?	199-200	Szombathy and Heinzel	1890	201	„Mumienschädel aus Peru, ded. Charles Wiener in Paris, Fundort Viru, Prov. Libertad. Cranium. Im linken Scheitelbein ein 3cm langes, 2cm breites Loch mit verheilten Rändern, davon ausgehend mehrere gleichfalls verheilte Fissuren. Beide Ansaes capitis gebrochen und mit Dislokation geheilt.“	“Mummy skull from Peru, ded. Charles Wiener in Paris, place of origin in Viru, Prov. Libertad. Cranium. In the left parietal bone there is a 3 cm long and 2 cm wide hole with healed edges, from which several fissures have healed. Both ansae capitis broken and healed with dislocation.”	Skeletonized skull
2872	OSTE: no. 1461 – 2894	Post XIX	?	199-200	Szombathy and Heinzel	1890	201	„Mumienschädel aus Peru, ded. Charles Wiener in Paris, Fundort Viru, Prov. Libertad. Cranium mit defektem Gebiss.“	“Mummy skull from Peru, ded. Charles Wiener in Paris, place of origin in Viru, Prov. Libertad. Cranium with defective jaw.”	Skeletonized skull
2874	OSTE: no. 1461 – 2894	Post XIX	?	199-200	Szombathy and Heinzel	1890	201	„Mumienschädel aus Peru, ded. Charles Wiener in Paris, Fundort Viru, Prov. Libertad. Stark deformiertes Cranium mit beginnender Obliteration.“	“Mummy skull from Peru, ded. Charles Wiener in Paris, place of origin in Viru, Prov. Libertad. Heavily deformed cranium with beginning obliteration.”	Skeletonized skull

Inv. no.	Inventory book				Inventoried by			Entry in the inventory book		Today present as
	Name	Section	Date	Page	Name	Date	Page	German	English	
2875	OSTE: no. 1461 – 2894	Post XIX	?	199-200	Szombathy and Heinzel	1890	201	„Mumienschädel aus Peru, ded. Charles Wiener in Paris, Fundort Viru, Prov. Libertad. Cranium, im Gegensatz zu den anderen nicht deformiert, mit besonders langen Process. [Processus] Styloidei.“	“Mummy skull from Peru, ded. Charles Wiener in Paris, place of origin in Viru, Prov. Libertad. Cranium, in contrast to the other not deformed, with particularly long styloid processes.”	Skeletonized skull
2876	OSTE: no. 1461 – 2894	Post XIX	?	199-200	Szombathy and Heinzel	1890	201	„Mumienschädel aus Peru, ded. Charles Wiener in Paris, Fundort Viru, Prov. Libertad. Mumienschädel in der ursprünglichen Montierung, mit einem Stück des Halses.“	“Mummy skull from Peru, ded. Charles Wiener in Paris, place of origin in Viru, Prov. Libertad. Mummy skull with the original mounting features, including part of the neck.”	Mummified head
2877	OSTE: no. 1461 – 2894	Post XIX	?	199-200	Szombathy and Heinzel	1890	201	„Mumienschädel aus Peru, ded. Charles Wiener in Paris, Fundort Viru, Prov. Libertad. Deformiertes Cranium mit besonders starker linea nuchae. Os interparietale.“	“Mummy skull from Peru, ded. Charles Wiener in Paris, place of origin in Viru, Prov. Libertad. Deformed cranium with particularly strong nuchal line. Inca bone.”	Skeletonized skull
4912	OSTE: no. 4783 – 9610	?	?	40	Szombathy	1915	55	„Skelett-Teile aus altägyptischen Flachgräbern von El Kubanieh in Oberägypten. Geschenk der kais. [kaiserlichen] Akademie der Wissenschaften. Ausgrabungen im Winter 1910/11 von Prof. Dr. Hermann Junker auf Akademiekosten. Die Erhaltung der Skelette wurde durch eine hierfür bestimmte besondere Subvention der mathematisch-naturwissenschaftlichen Klasse der Wiener Akademie der Wissenschaft ermöglicht. NB. [nota bene/	“Skeleton parts from ancient Egyptian flat graves from El Kubanieh in Upper Egypt. Gift of the Imperial Academy of Sciences. Excavations in winter 1910/11 by Prof. Dr. Hermann Junker at the expense of the Academy. The preservation of the skeletons was made possible by a special subsidy from the mathamatic-natural science class of the Vienna Academy of Science. NB. [note?] In the El Kubanieh cemetery 5 age groups	Skeletonized skull

								Anmerkung?] Im Gräberfeld El Kubanieh sind 5 Altersstufen zu unterscheiden: Frühzeit A (Fr.A.), Frühzeit B (Fr.B.), Mittleres Reich (M.R.), Neues Reich (N.R.) und Byzantinisch (Byz.). Calvarium, adult, aus den mumifizierten Geweben herauspräpariert, daher ohne Defekt. Z.[Zähne] [Oberkiefer rechts] 8 6 (5) 4 [Oberkiefer links] 1 2 5 6 (8 im Kiefer steckend, falsch gelagert). Am Pterion r. [rechts] ein Fraßlöchlein.“	can be distinguished: Early Period A, Early Period B, Middle Kingdom, New Kingdom and Byzantine. Calvary, adult, prepared from the mummified tissue, therefore without defect. Teeth. [Maxilla right] 8 6 (5) 4 [Maxilla left] 1 2 5 6 (8 stuck in the jaw, incorrectly positioned). Insect hole at the right pterion.”	
5036	OSTE: no. 4783 – 9610	?	?	65-66	Szombathy	1919	71	„Zwei Altperuaner – Schädel gesam. [gesammelt] u. [und] geschenkt von Graf Eduard Wickenburg, 1916. Cranium, sehr wohl erhalten, einer Mumie entnommen. Die Nähte offen, sehr stark vortretender Arcus supraciliaris. Z [Zähne]: [Oberkiefer links] 7 (5) 4 3 [Oberkiefer rechte] 3 4 5 6 7 [Unterkiefer links] 6 5 4 2 1 [Unterkiefer rechts] 3 5 8. Die vorhandenen Zähne besonders stark abgekaut. Dazu gehört eine Partie der Kopfhaut mit dunkelbraunen Haaren. Graf Wickenburgs Verzeichnis Nr. 103.“	“Two ancient Peruvian skulls collected and donated by Count Eduard Wickenburg, 1916. Cranium, very well preserved, taken from a mummy. The sutures open, very strongly protruding superciliar arcus. Teeth: [Maxilla left] 7 (5) 4 3 [Maxilla right] 3 4 5 6 7 [Mandible left] 6 5 4 2 1 [Mandible right] 3 5 8. The existing teeth chewed off particularly badly. It includes a part of the scalp with dark brown hair. Count Wickenburg's register no. 103.”	Skeletonized skull

Inv. no.	Inventory book				Inventoried by			Entry in the inventory book		Today present as
	Name	Section	Date	Page	Name	Date	Page	German	English	
5037	OSTE: no. 4783 – 9610	?	?	66	Szombathy	1919	71	„Zwei Altperuaner - Schädel gesam. [gesammelt] u. [und] geschenkt von Graf Eduard Wickenburg, 1916. Cranium einer Mumie, mit offenen Nähten und mäßig abgeflachter Stirn, sehr prognath. Z [Zähne]: [Oberkiefer links] 7 6 5 4 [Oberkiefer rechte] 3 4 6 7 [Unterkiefer links] 4 2 3 [Unterkiefer rechts] 2 3 4 5 6 7 8. NB. [nota bene/ Anmerkung?] Nur die Pfeilnaht in beginnender Obliteration. Dazu gehört eine Probe der Kopfhaut mit dunkelbraunen Haaren. Graf Wickenburgs Verzeichnis Nr. 104. NB. [nota bene/ Anmerkung?] Genauere Fundortsangaben fehlen.“	“ Two old Peruvian skulls collected and donated by Count Eduard Wickenburg, in 1916. Cranium of a mummy, with open sutures and moderately flattened forehead, very prognathic. Teeth: [Maxilla left] 7 6 5 4 [Maxilla right] 3 4 6 7 and in the lower jaw [Mandible left] 4 2 3 [Mandible right] 2 3 4 5 6 7 8. NB. [note?] Only the sagittal suture in beginning obliteration. This includes a sample of the scalp with dark brown hair. Count Wickenburg's Directory No. 104. NB. [note?] Exact location information is missing.”	Skeletonized skull
5042	OSTE: no. 4783 – 9610	?	?	68	Szombathy	1919	71	„Ägyptische Mumien Schädel. Calvarium aus einem Flachgrab bei den Pyramiden von Gizeh. Geschenk von Hofr. [Hofrat] Friedrich Schlägl, der den Schädel angesichts der Ausgrabungen erwarb. Das r. [rechte] Jochbein und die anschließenden Oberkiefer teile fehlen. Die Nähte 1/4 verwachsen. Von der vollständigen Bezahnung sind vorhanden 7, 6 l. [linksseitig im Oberkiefer].“	“Egyptian mummy skulls. Calvary from a flat grave near the pyramids of Giza. Gift from advisory council Friedrich Schlägl, who acquired the skull in consideration of the excavation. The right zygomatic bone and the adjoining upper jaw parts are missing. The sutures of the skull have fused a fourth. Of the entire dentition there are present 7, 6 l. [teeth 7 and 6 of the left maxilla].“	Skeletonized skull

Inv. no.	Inventory book				Inventoried by			Entry in the inventory book		Today present as
	Name	Section	Date	Page	Name	Date	Page	German	English	
5043	OSTE: no. 4783 – 9610	?	?	68	Szombathy	1919	71	„Vollständiger Schädel mit den anhaftenden Weichteilen und einem Teil des Halses, noch von einigen Binden umgeben. Angeblich von Theben. Geschenk von Ludwig Hans Fischer.“	“Complete skull with the attached soft tissues and part of the neck, still surrounded by some bandages. Allegedly from Thebes. Gift of Ludwig Hans Fischer.”	Mummified head
5877	OSTE: no. 4783 – 9610	?	?	217	Szombathy	1928	283	„Luxor Mumienisch. [Mumienschädel]. Mumienschädel. Geschenk d. [des] Dr. Richard Kulka. Adr. [Adresse] siehe oben [6. Mariahilferstraße 109] mit d. [der] Angabe: »M. Sch. [Mumienschädel] erworben 1913 in Luxor«.“	“Mummy skull from Luxor. Mummy skull. Gift of Dr. Richard Kulka. Address see above [6. Mariahilferstraße 109] with the specification: »Mummy skull acquired 1913 in Luxor«.”	Mummified head
9200	OSTE: no. 4783 – 9610	?	?	610	?	?	?	Mumienschädel aus der Sammlung von A. Weisbach: „Schädel einer gut erhaltenen Mumie und die 3 ersten Halswirbel. Sehr gut erhalten. 1 Brustwirbel. Langkopf mit hohem schmalem Gesicht, braune Haare mit deutlich rötlichem Stich, hohe schmale Nase, relativ kleine Ohren.“	Mummy skull from the collection of A. Weisbach: “Skull of a well-preserved mummy and the first three cervical vertebrae. Very well preserved. One thoracic vertebra. Long head with high narrow face, brown hair with distinct reddish tinge, high narrow nose, relatively small ears.”	Mummified head
14726	OSTE: no. 9611 – 5099	?	?	452	Wastl	1935	508	Altägyptischer Mumienkopf. Mumienkopf und Hand: Auskunft des Herrn Skalitzki [Karl Skalitzky].“	“Ancient Egyptian Mummy skull. Mummy skull and hand: Information by Mr. Skalitzki [Karl Skalitzky].“	Mummified head
15378	OSTE: no. 15100 – 21316			70-71	Wastl	1935	72	„Mumienkopf (ägyptisch). Geschenk des Herrn Richard Klein, 17.9.1935, 4. Karlsgasse 16.“	“Mummy skull (Egyptian). Present of Mr. Richard Klein, Nov. 17th 1935, 4. Karlsgasse 16.”	Mummified head

3.2 Collectors

Twenty out of the 23 skeletonized skulls or mummified heads, mentioned in the inventory book of the Department of Anthropology and in Table 24, came to the Natural History Museum through the activities of 13 persons. Only for the three inventory numbers **1523**, **1525**, **1526** no information about their collectors could be retrieved from the inventory book. Table 24 shows names and dates of birth and death of the collectors and the skulls which they brought to the Museum. Because no entry in the inventory book about number **5**, **also called** "The Clay Face" is available, there is also no information about the collector.

A short biography of the respective collector follows, with an indication of the connection to the individual objects.

Table 24. List of the various collectors attributed to the skulls that are discussed in this thesis.

Collectors name	Year of birth and death	Collected skull/head
Cohn, Salo	1842 – 1917	2229, 2231
Fischer, Ludwig Hans	1848 – 1915	5043
Junker, Hermann	1877 – 1962	4912
Klein, Richard	1881 – ?	15378
Kulka, Richard	1863 – 1931	5877
Leuthner, Franz	?	2859
Marno, Ernst	1844 – 1883	28
Schlögl, Friedrich	1821 – 1892	5042
Skalitzky, Karl	1841 – 1914	14726
Weisbach, Augustin	1837 – 1914	9200
Wickenburg, Eduard	1866 – 1936	5036, 5037
Wiener, Charles	1851 – 1913	2871, 2872, 2874, 2875, 2876, 2877
Kronprinz Rudolf	1858 – 1989	2478

3.2.1 Salo Cohn

According to the card catalogue (Figure 23 A) and Szilvassy & Kentner (1978), Salo Cohn (1842 – 1917) donated human remains to the Natural History Museum of Vienna in 1885. This is noted in the inventory book as follows: "Racial skulls and pelvis collected by Dr. Augustin Weisbach [...] Present from Mr. Salo Cohn in Vienna, 1885. Purchase price 2000 guilders." Therefore, this collection, with inventory numbers 1612 - 2312, was collected by Dr. Augustin Weisbach and later acquired by the Natural History Museum in Vienna through Salo Cohn. Further information about the connection between Weisbach and Cohn could not be obtained so far. Among this collection there are two skulls (inventory numbers **2229** and **2231**) which are mentioned in this work because they probably were acquired in a mummified status and were treated later (unknown date, procedure or technician) to eliminate soft tissue.

Salo Cohn lived in Vienna between 1842 and 1917 and worked as a banker, cult leader and philanthropist (Alker-Windbichler et al., 2008). Unfortunately, no more information about him is available.

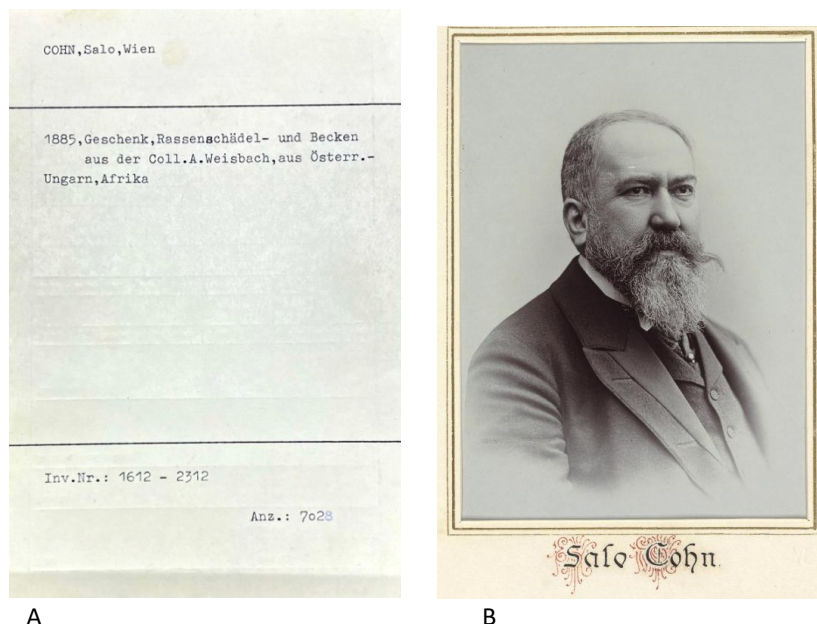


Figure 23. A: Entry about Salo Cohn in the card catalogue of the Department of Anthropology of the Natural History Museum in Vienna (Card Catalogue. Category: Collectors. Consulted on 19 August 2021., n.d.); B: Picture of Salo Cohn (© ÖNB (ÖNB Digital, 1902).

3.2.2 Ludwig Hans Fischer

Ludwig Hans Fischer (1848 – 1915) donated the mummy skull with inventory number **5043** to the Natural History Museum Vienna (Figure 24 A). The exact circumstances under which he collected or acquired this head are (still) unknown, as there is nothing written down about bone collections by L.H. Fischer in the archives analyzed so far.

Ludwig Hans Fischer (Figure 24 B) was born on 2nd March 1848 in Salzburg, Austria. Fischer was a painter, graphic artist, draughtsman and illustrator. In 1875 he went on his first trip to Tunisia, Libya, Egypt, Palestine and Asia Minor. He also made further trips to Egypt in 1880, 1887, 1891 and 1897. It is possible that he took the Theban mummy skull 5043 home with him on one of these many trips to Egypt, probably when he was in Luxor in 1887 (Thebes is located on the opposite side of the Nile). Furthermore, Fischer was a member of the Anthropological and Prehistoric Society of Vienna and is described as having painted eight murals in the showrooms of the Hochparterre in the Natural History Museum in Vienna between 1882 and 1889 (Figure 24). Fischer died on 24th April 1915 in Vienna, Austria (Österreichischen Akademie der Wissenschaften, 1957).

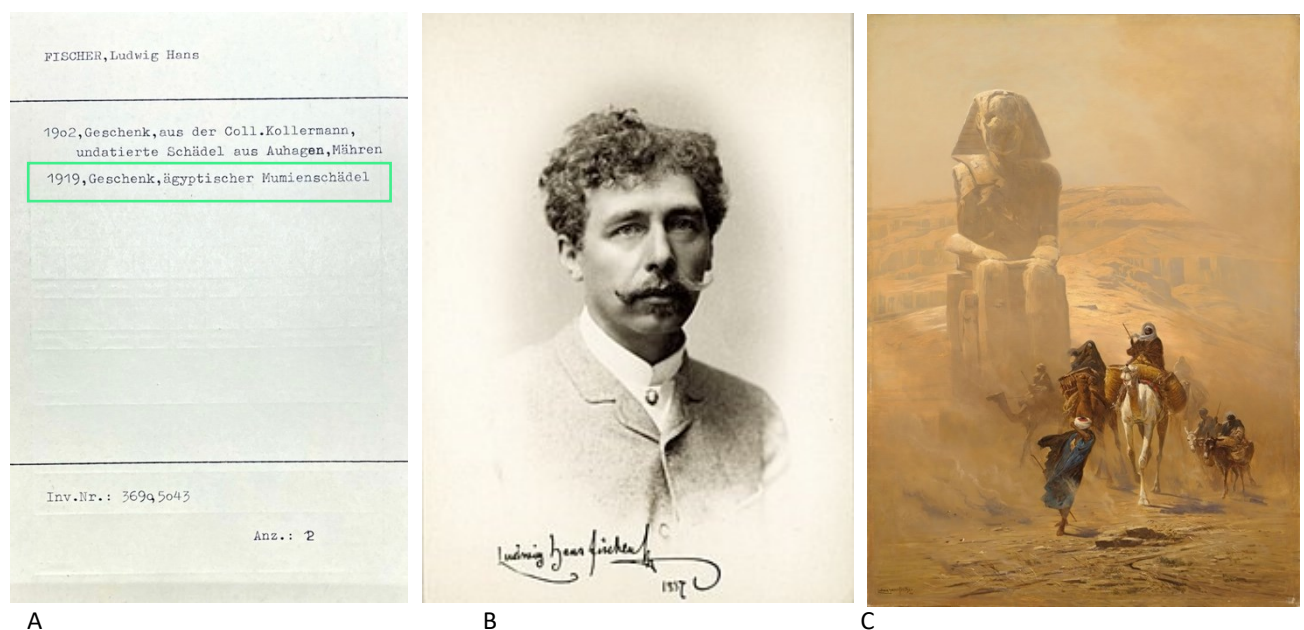
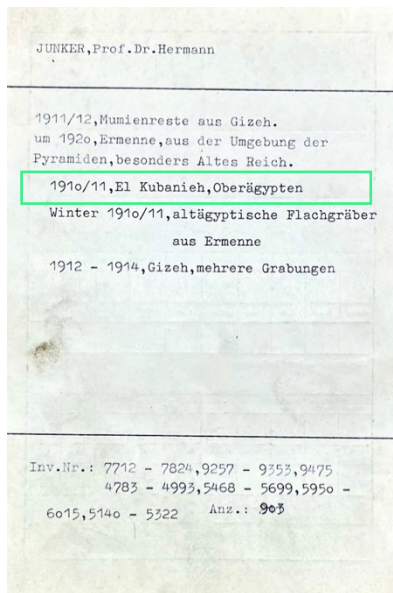


Figure 24. A: Entry about Ludwig Hans Fischer in the card catalogue of the Department of Anthropology of the Natural History Museum in Vienna (Card Catalogue. Category: Collectors. Consulted on 19 August 2021., n.d.); B: Picture of Ludwig Hans Fischer (© Wikimedia Commons; https://commons.wikimedia.org/wiki/Category:Ludwig_Hans_Fischer). C: One of Fischer's paintings, called "The Khamsin" (*The Khamsin* (1891), n.d.).

3.2.3 Hermann Junker

As a result of the excavations at El Kubanieh, Egypt, in the winter of 1910/11, the skull with the inventory number **4912** was among the items that came to the Natural History Museum by Prof. Dr. Hermann Junker (Figure 25 A). Many other excavation sites in Egypt, excavated by Junker, resulted in the abundant material still present at the museum.

Hermann Junker (1877 – 1962) (Figure 25 B) was born on the 29th of November 1877 in Bendorf am Rhein, Germany. His family was profoundly Catholic, which is why he started to study theology. In the course of this he also studied Egyptology, and some other disciplines (1896-1903). In 1907 Junker habilitated at the University of Vienna and was significantly involved in establishing the subjects of Egyptology and African Studies in Austria. On behalf of the Austrian Academy of Sciences, Hermann Junker led a large number of archaeological excavations in Egypt from 1909 onwards. These included excavations in El-Kubanieh, Giza, Ermenne and Toshke. His excavation projects and activities ended with the beginning of the Second World War. He remained faithful to Austria and the Austrian Academy of Sciences, even though he had his main residence in Germany over the last decades before his death. Hermann Junker died on January 9, 1962 in Vienna. According to a decision of the Austrian Academy of Science, the skeletons collected by Hermann Junker (950 inventory numbers) were donated to the Anthropological-Ethnographic Department, that was split in 1926 and ended up in the Department of Anthropology of the Natural History Museum Vienna (Gütl, 2010, 2017).



A



B

Figure 25. A: Entry about Hermann Junker in the card catalogue of the Department of Anthropology of the Natural History Museum in Vienna (Card Catalogue. Category: Collectors. Consulted on 19 August 2021., n.d.); B: Picture of Hermann Junker (Reproduction with courtesy of Archiv der Universität Wien, 106.I.1225).

3.2.4 Richard Klein

Unfortunately, nothing could be found about Mr. Richard Klein (1881-?) in the databases of the Department of Anthropology in Vienna. He was only mentioned in the inventory book as having donated the mummy skull with inventory number **15378** to the Natural History Museum in Vienna.

Richard Klein was born on first September 1881 in Vienna, Austria. From 1921, Mr. Klein was the owner of an antique shop and around 1931 his business address was Karls gasse 16 in the fourth district of Vienna (Anderl, 2009). This address is also listed in the inventory book under inventory number 15378. Unfortunately, there is very little information about Mr. Klein, so it is not known at all how he acquired mummies.

3.2.5 Richard Kulka

The mummy skull with the inventory number **5877** came to the Natural History Museum in Vienna, as a gift by Richard Kulka (1863 – 1931). In the card catalogue, however, only the previous inventory number 5876 from Damiette, Egypt, and the following inventory

number 5878 from Waagtal, Slovakia, are mentioned (Figure 26). Inventory number 5877 from Luxor, Egypt, is missing. This is possibly due to the fact that this mummy skull is noted as “missing” in the inventory book.

Richard Kulka was born on 13th March 1863 in Leipnik, Czech Republic. In 1890 he completed his studies in law at the University of Vienna. In the inventory book Kulka appears with the address "Mariahilferstraße 109", which according to Stelzl-Gallian (2014) he had owned since 1905. Besides his profession as a lawyer, he had various other interests. One of them was anthropology, where he had been a member of the Anthropological Society in Vienna since 1889 and in 1894 he joined the Association for Ethnology. Richard Kulka was also a passionate photographer and painter. He donated many of his photographs and paintings to various museums. He was also very generous with monetary donations. For example, some donations went to the Museum of Ethnology and the Prehistoric Society in Vienna and a certain part of his bequest went to the Anthropological Society of Vienna (Stelzl-Gallian, 2014). Even in the annual report of the Anthropological Society in Vienna (Christian, 1932), Mr. Kulka was mentioned by name and he was thanked for his many years of work as an auditor. Based on the accessed literature, it was not possible to find out how his collections of human remains came about. Richard Kulka died in Vienna on 7th December 1931 at the age of 68 years.

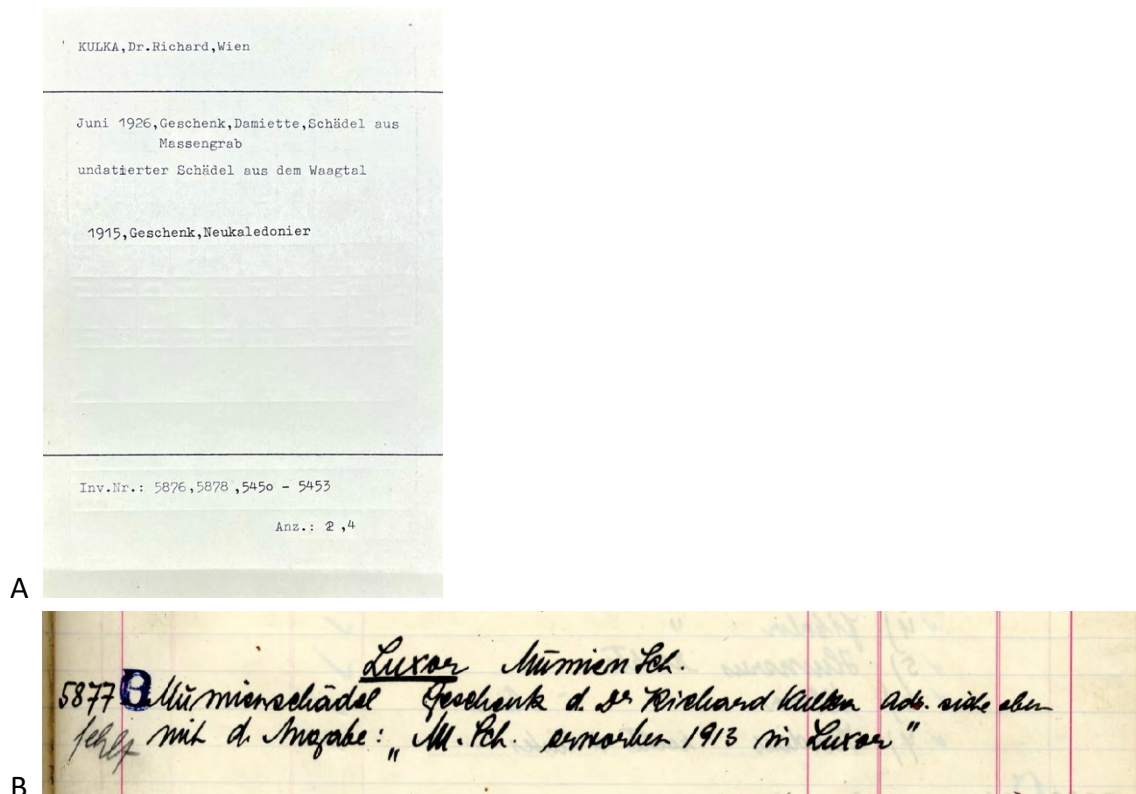


Figure 26. A: Entry about Richard Kulka in the card catalogue of the Department of Anthropology of the Natural History Museum in Vienna (Card Catalogue. Category: Collectors. Consulted on 19 August 2021., n.d.). The mummy skull attributed to Richard Kulka is not listed here. B: Entry for the inventory number 5877 in the inventory book of the anthropological collections of skeletons (OSTE, no. 4783 to 9610 on page 68) shows the mention of the name Richard Kulka.

3.2.6 Franz Leuthner

In the inventory book, „Dr. Leuthner“ (Figure 27), who is mentioned under inventory number **2859**, probably refers to the insect specialist Mr. Franz Leuthner (Ganglbauer, 1901). In the annual report for 1886, the Annals of the Natural History Museum, his name is mentioned four times and the following gifts to the Natural History Museum in Vienna enriched the collection: a small collection of mammals, a mummy skull from Luxor (this is the mummy skull with inventory number 2859), an insect collection and an arachnoid collection (Hauer, 1887). In another issue of the Annals of the Natural History Museum Leuthner is thanked for work at the museum (Hauer, 1886). Unfortunately, no further information or pictures could be found about Mr. Leuthner.

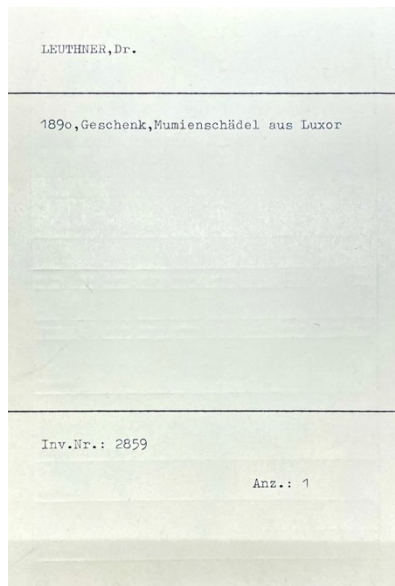
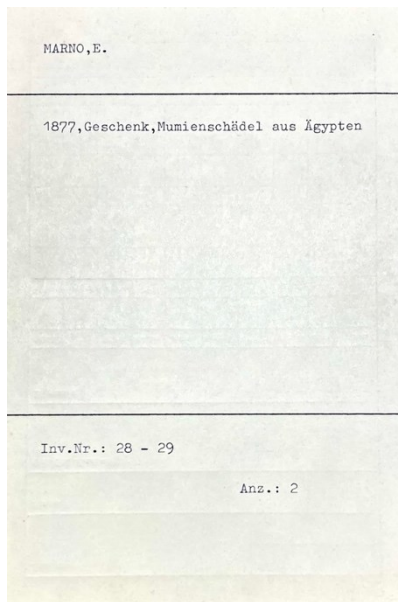


Figure 27. Entry about Dr. Leuthner in the card catalogue of the Department of Anthropology of the Natural History Museum in Vienna (Card Catalogue. Category: Collectors. Consulted on 19 August 2021., n.d.).

3.2.7 Ernst Marno

According to the card catalogue (Figure 28 A) and Szilvassy & Kentner (1978), Ernst Marno (1844 – 1883) donated the Egyptian mummy skull with inventory number **28**, as well as a mummified arm (inventory number 29), which is not further mentioned herein, to the Natural History Museum in Vienna (Figure 28 A).

Ernst Marno (Figure 28 B) was born on 13th January 1844 in Vienna, Austria. He studied zoology, which he soon abandoned, and then devoted himself exclusively to the exploration of Africa. During one of his many different trips to Egypt, he probably acquired the two mummified body parts. At one of his journeys, Ernst Marno died at the young age of 39 years, on 31th January 1883 in Sudan (Lindgren, 1990; Österreichischen Akademie der Wissenschaften, 1975).



A



B

Figure 28. A: Entry about Ernst Marno in the card catalogue of the Department of Anthropology of the Natural History Museum in Vienna (Card Catalogue. Category: Collectors. Consulted on 19 August 2021., n.d.); B: Picture of Ernst Marno (© Öst. Nationalbibliothek, Wien).

3.2.8 Crown Prince Rudolf of Austria

The mummy skull with the inventory number **2478** came to the Natural History Museum due to the bequest of Crown Prince Rudolf (1858 – 1889). According to the card catalogue (Figure 29 A) on 30th July 1889, skulls and plaster skulls of various origins in Europe, Africa and New Zealand were acquired from the bequest. This includes the following inventory numbers: 2471-2483 and 2488-2489.

Crown Prince Rudolf (Figure 29 B) was born on 21st August 1858 in Laxenburg, Austria. He began to study natural sciences at an early age and especially devoted himself to ornithology. Rudolf also undertook many journeys, always for the purpose of studying the animal world, the countries and the people. In 1881, a journey took him to Egypt. Probably on this journey the crown prince returned with the mummy skull 2478. Due to his depression, which led to drug and alcohol consumption, he finally committed suicide on 30 January 1889 (Blasius, 1889; Österreichischen Akademie der Wissenschaften, 1987). At least some of his bequest related to science was then transferred to the Natural History Museum in Vienna.

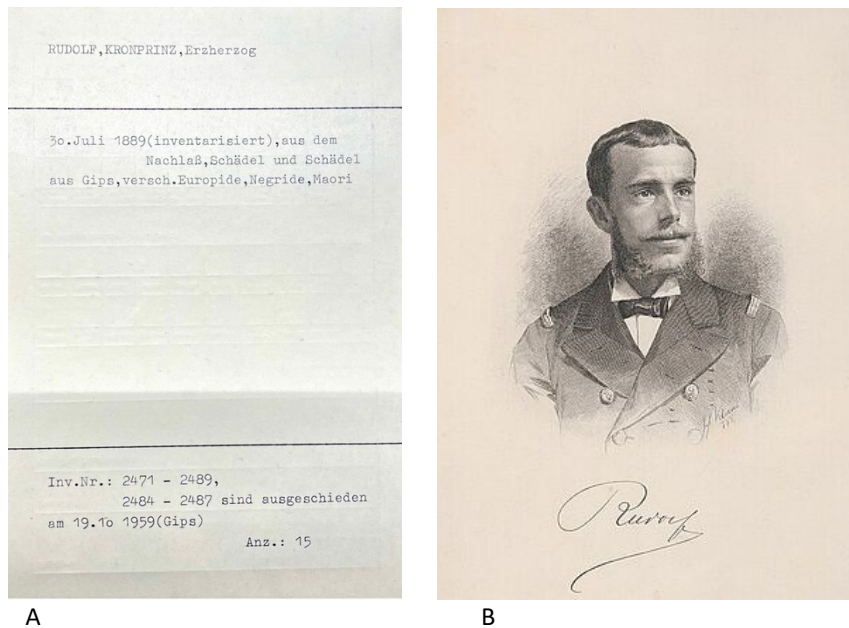


Figure 29. A: Entry about Crown Prince Rudolf in the card catalogue of the Department of Anthropology of the Natural History Museum in Vienna (Card Catalogue. Category: Collectors. Consulted on 19 August 2021., n.d.); B: Picture of Crown Prince Rudolf made by Johann Klaus (© Öst. Nationalbibliothek, Wien; BAG FID 240.670-D).

3.2.9 Friedrich Schlögl

The already skeletonized mummy skull with the inventory number **5042** came to the Natural History Museum in Vienna, as a gift by Friedrich Schlögl (1821 – 1892). He acquired this skull as part of an excavation process. Also in the card catalogue, this is the only skull attributed to Mr. Schlögl (Figure 30 A).

Friedrich Schlögl (Figure 30 B) was born on 7th December 1821 in Vienna, Austria. In the 1840s, he already began to write, and after 1870, Mr. Schlögl devoted himself entirely to journalism and writing. He wrote numerous important articles on 1873, 1876 or 1883 in various newspapers on his "Viennese Life Pictures". Friedrich Schlögl probably acquired the Egyptian skull 5042 during a trip to Egypt, where he was working as a travel correspondent. Mr. Schlögl died in Vienna on 7th October 1892, at an age of 70 years (Österreichischen Akademie der Wissenschaften, 1994).

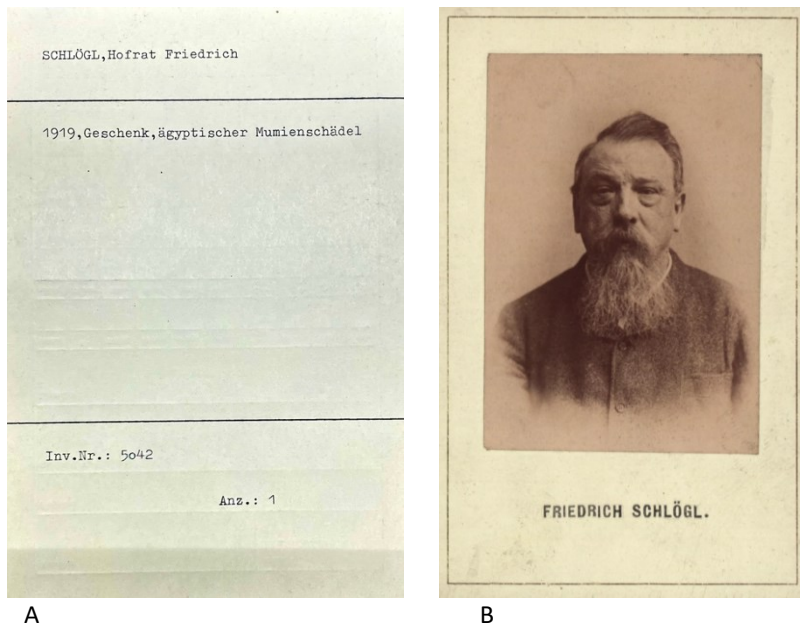


Figure 30. A: Entry about Friedrich Schlögl in the card catalogue of the Department of Anthropology of the Natural History Museum in Vienna (Card Catalogue. Category: Collectors. Consulted on 19 August 2021., n.d.); B: Picture of Friedrich Schlögl (© Wien Museum Inv.-Nr. 103491/2, CC0 (<https://sammlung.wienmuseum.at/objekt/520977/>)).

3.2.10 Karl Skalitzky

Karl Skalitzky (1841 – 1914) is not mentioned in the collectors card catalogue of the Department of Anthropology of the Natural History Museum in Vienna. He is shortly mentioned in the context of the mummy skull with the inventory number **14726**. However, it is not quite clear what is meant by the entry "Information from Mr Skalitzky" in the inventory book and whether Mr Skalitzky can be associated at all with the collection of skull 14726.

Karl Skalitzky (Figure 31), who was born on 17th April 1841 in Prague, Czech Republic, had an extraordinary interest in entomology and especially in coleopterology. He also developed his great collecting experience in the areas of Hermannstadt in Transylvania, in the surroundings of Vienna, Windischgarsten, Pragsertal, Golling, Gmain and Gastein. Nothing is known about any collections of skulls or mummies by him, nor about any collecting areas in Egypt, from which skull 14276 comes. Due to the intensive correspondence between Skalitzky and many other renowned collectors in the field of coleopterology, there may also have been exchanges of human remains among them. Karl

Skalitzky retired in 1906 and spent the rest of his time in Vienna until his death on the 23rd of April 1914 ("Bericht Der Sektion Für Koleopterologie," 1915).

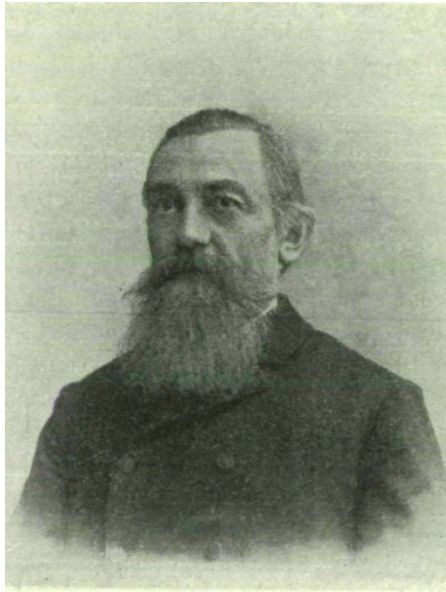


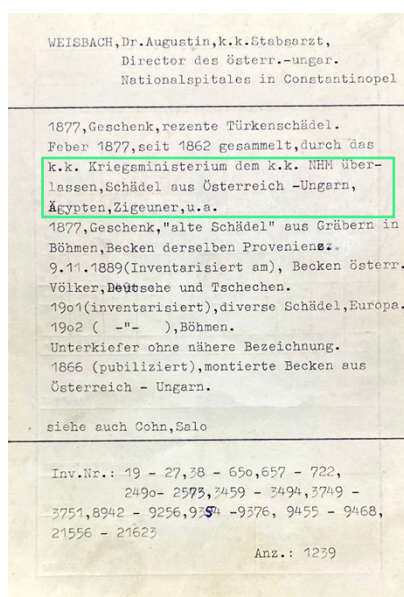
Figure 31. Picture of Karl Skalitzky ("Bericht Der Sektion Für Koleopterologie," 1915, p. 196).

3.2.11 Augustin Weisbach

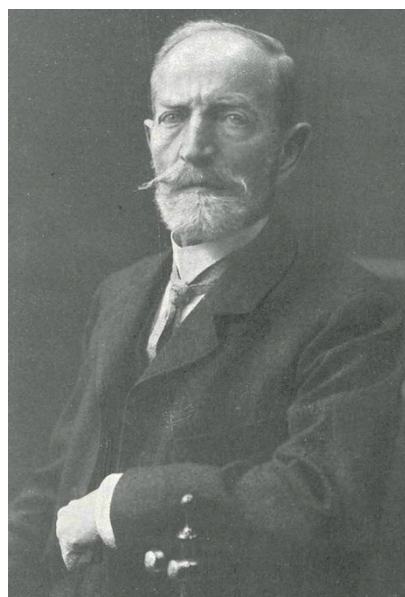
Augustin Weisbach collected numerous skulls curated in the Department of Anthropology of the Natural History Museum in Vienna. These include the skulls with the inventory numbers 2229, 2231 and the mummy skull **9200**. However, the skulls 2229 and 2231 were donated to the Natural History Museum Vienna by Salo Cohn in 1885 and were not donated to the museum by Weisbach (see Biography on Salo Cohn above). There is no information on when the 9200 skull was handed over to the museum or on detail of how he obtained it. The excerpt from the card catalogue shows the large number of objects collected by Weisbach (Figure 32 A).

Augustin Weisbach (Figure 32 B) was born on the 17th of July 1837 in Komotau, Czechia. In 1861 he completed his doctoral studies and became a senior physician at the Imperial and Royal Army. When he began to work with Prof. Dr. Josef Engel on the pathological and topographical army, he developed a special interest for skull collections. The writings of Andreas Retzius lead him to investigate the differences in type between various

Austrian peoples. Weisbach developed a craniometric measuring system that identified the shape of the skulls of different Austrian peoples. He made another important anthropological contribution to type differences of diverse peoples when he examined the anthropological collections retrieved during the expedition of the ship Novara (1857 – 1859) in 1866. Dr. Augustin Weisbach also examined a large number of very different skulls, including those he called “Turks”, the “Austrian Alpine people”, as well as the prehistoric skulls from Bosnia and Herzegovina and Romania. On April the 17th 1914 Augustin Weisbach died at the age of 77. Augustin Weisbach was a major contributor to the study of racial divisions and the differentiation of various ethnic groups. He thus laid a “scientific” foundation for racial studies and provided an extensive and thus ethically complex and sensible collection of skulls to the Natural History Museum Vienna (Khull-Kholwald, 1915; V. O. Vyslozil et al., 1996).



A



B

Figure 32. A: Entry about Augustin Weisbach in the card catalogue of the Department of Anthropology of the Natural History Museum in Vienna (Card Catalogue. Category: Collectors. Consulted on 19 August 2021., n.d.); B: Portrait of Augustin Weisbach (Khull-Kholwald, 1915, p. 7).

3.2.12 Eduard Wickenburg

Two ancient Peruvian skulls with the inventory numbers **5036** and **5037** were collected and donated (1916) to the Natural History Museum in Vienna by Count Eduard

Wickenburg (1866 – 1936). These two skulls are the only ones mentioned in the card catalogue under this name (Figure 33 A).

Eduard Wickenburg (Figure 33 B) was born on 3rd July 1866 in Rohrbach, Austria. Wickenburg was a passionate traveler. His travels took him to all continents. His last trip before World War II was from 1911 to 1913 to South America. Wickenburg collected a mummy skeleton from Bolivia and a mummy wrapping from Peru, both of which were donated to the k.k. Naturhistorisches Hofmuseum (old designation for the Natural History Museum in Vienna). Possibly the Peruvian wrapping corresponds to one of the two Peruvian mummies with inventory numbers 5036 and 5037 from the Natural History Museum, mentioned in this work. Furthermore, Wickenburg donated about 200 objects from his large collection (including stone artefacts, remains of insects and birds, large animals, several amphibians and reptiles as well as wagons and tools from Somaliland) to the Department of Anthropology and Ethnography of today's Natural History Museum of Vienna. Eduard Wickenburg died during one of his mountain tours in Austria in 1936 at the age of 70 (Österreichischen Akademie der Wissenschaften, 2019; *Wickenburg, Eduard Graf*, 2009).

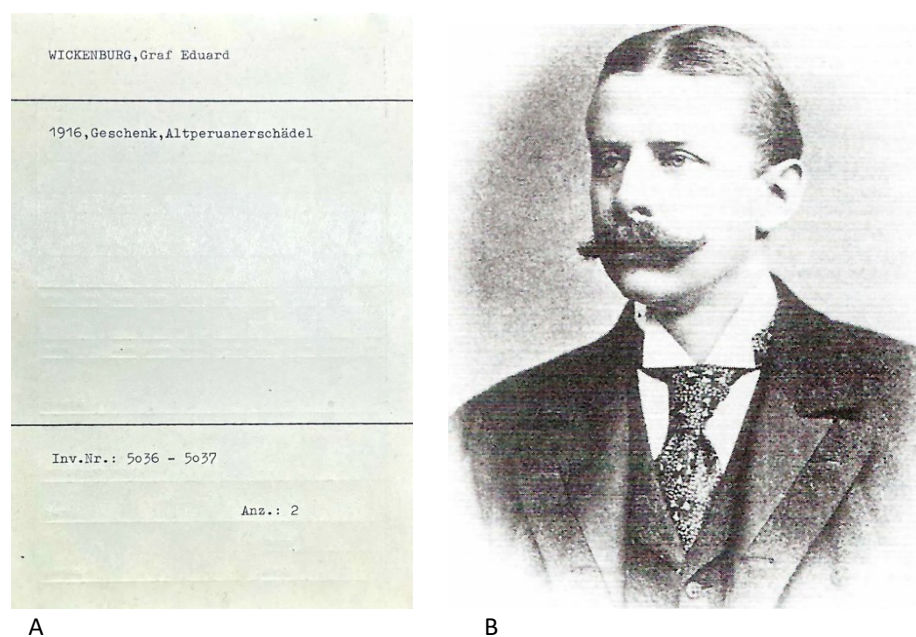
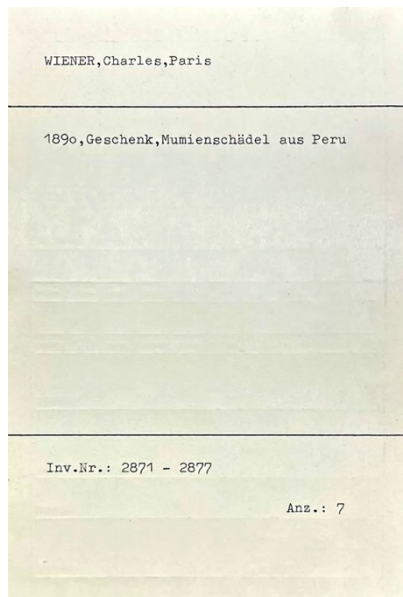


Figure 33. A: Entry about Graf Eduard Wickenburg in the card catalogue of the Department of Anthropology of the Natural History Museum in Vienna (Card Catalogue. Category: Collectors. Consulted on 19 August 2021., n.d.); B: Picture of Graf Eduard Wickenburg (© Archiv Senft (Wickenburg, Eduard Graf, 2009)).

3.2.13 Charles Wiener

Charles Wiener (1851 – 1913) sent the following six skulls, analyzed herein, to the National History Museum in Vienna: **2871, 2872, 2874, 2875, 2876, 2877** (Figure 34 A). An exact date is not given, but the date of the person responsible for the inventory (Josef Szombathy) showed, that this happened before the year 1890.

Charles Wiener (Figure 34 B) was born in December 1851 in Vienna, Austria. He moved to Paris at an early age and later became a French citizen. A scientific expedition took him to Peru and Bolivia. There, between 1875 and 1877, he collected over 4000 objects, most of which can still be seen at the French museum "Musée du Quai Branly". The book "Pérou et Bolivie", published by Charles Wiener in 1880, is one of his masterpieces, which describes his explorations and provides many helpful illustrations. Nevertheless, there are some critical perspectives on the accuracy and scientific accuracy. Some describe Wiener's deliverance as sloppy and unscientific and accuse him of unethical behavior (Stuiber, 2021). However, the Imperial collections in Vienna benefited from Wiener's expedition, so that today, more than 130 ethnographic objects collected by him are at the Weltmuseum in Vienna. Later in life, Wiener embarked on a diplomatic career and served as consul in Chile, Mexico, Paraguay, Bolivia, Uruguay and Venezuela. Charles Wiener later died in Rio de Janeiro in 1913 at the age of 62 (Stuiber, 2021; Verneau, 1919).



A



B

Figure 34. A: Entry about Charles Wiener in the card catalogue of the Department of Anthropology of the Natural History Museum in Vienna (Card Catalogue. Category: Collectors. Consulted on 19 August 2021., n.d.); B: Dateless portrait of Charles Wiener, made by the photographer Alexandre Quinet (source: gallica.bnf.fr/Bibliothèque nationale de France).

3.3 Distribution of the skulls and mummified heads by country

It should be said in advance that those skulls/heads that have been assigned to a certain country do not necessarily have to be from that country of origin.

All 24 skulls/heads analyzed herein could be ascribed to either one of three countries: Peru, Egypt or New Hebrides (Figure 37). For eight of the skulls/heads only the country of origin was given by the entry of the inventory book or by assigning them to a country of origin with the help of international scientific cooperation. For 16 of the 24 entries the more exact region (city) where they came from is cited in the inventory book.

The following inventory numbers are attributed to **Egyptian origin** (Figure 37): 28, 2229, 2231, 2467, 2859, 4912, 5042, 5043, 5877, 9200, 14727, and 15378. Inventory numbers 28 and 5043 were found in Thebes 2859 and 5877 came from the region of Luxor, 4912 was excavated in El Kubanieh, 2478 is from Manfalut and 5042 was found in Giza.

Unfortunately, the country of origin of the mummy 9200 is not indicated in the inventory book. However, personal conversations with Bernardo Arriaza (University Tarapaca, Chile - January 30, 2021), Jamie Dau and Maria Fernanda Boza (Centro Peruano de Arqueología Marítima y Subacuática, Peru - October 15, 2021), accompanied by the inspection of images and CT scans to visually reconstruct the method of mummification via zoom, the origin of this mummified head was attributed by all these specialists to Egypt.

When using forensic cranial features (Blumenfeld 2000; Caple & Stephan 2017), the skull 9200 can be associated to an African origin. These include: a long and narrow head with a rounded occipital profile, a small post-bregmatic depression, a rather rounded frontal profile, a prognathic jaw and a broad nasal aperture. Figure 35 shows the skull of 9200 (A, B) compared to the very different Peruvian mummy skull 2876 (C, D).

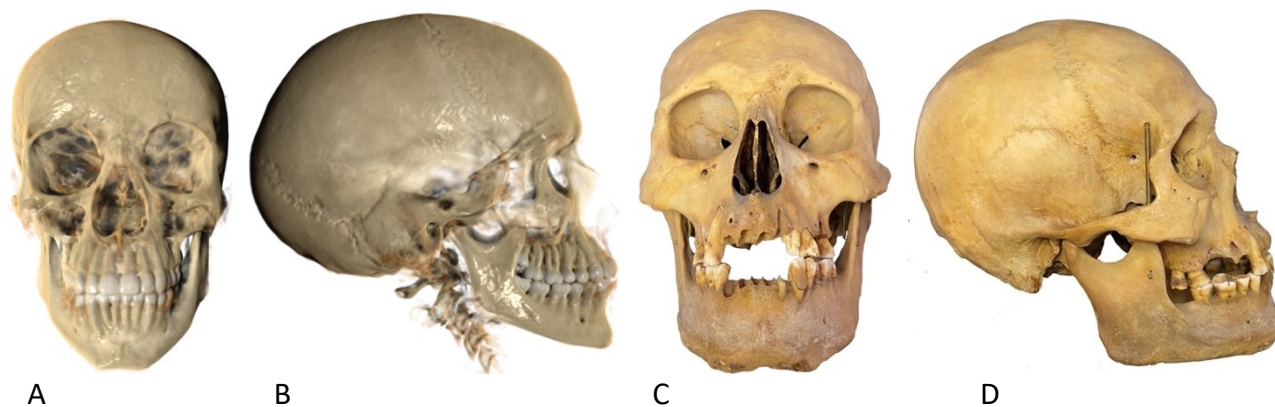


Figure 35. Frontal (A) and sagittal (B) profile of the mummy 9200 and frontal (C) and sagittal (D) profile of the Peruvian skeletonized skull 2875.

Skulls described as from Peruvian origin include the following inventory numbers (Figure 37): 1523, 1525, 1526, 2871, 2872, 2874, 2875, 2876, 2877, 5036, 5037. Nine from those 11 inventory numbers were discovered on the west coast of Peru: 1523 in Chancay, 1525 in Ancon, 1526 in Gran Chimú and the numbers 2871, 2872, 2874, 2875, 2876 and 2876 were found in Viru.

Unfortunately, number 5 "The Clay Face" cannot be assigned to any country since this skull was not found to be mentioned in the inventory book. But some of the following information suggests the New Hebrides Archipelago as origin.

Rüdinger (1888) describes intentionally modified skulls of the New Hebrides inhabitants (Vanuatu) whose morphological features corresponds with the features observed in this mummy head 5 "The Clay Face". According to Rüdinger (1888), skulls from Vanuatu have a long cylindrical skull shape, which is the result of a circular lacing that starts at the forehead and continues upwards and backwards wrapped around the head during the first years of life. This type of skull shape is also known as circumferential intentional modification (Buikstra & Ubelaker, 1994). In Figure 36 D, Rüdinger (1888) illustrates a typical form of circumferential head shape of the New Hebrides. This figure shows the similarities in skull shape between mummy 5 "The Clay Face" and the illustration of a typical Vanuatu skull.

An e-mail exchange with the collection assistant of the World Museum Vienna, Mag. Reinhard Blumauer, also suggests a New Hebridean origin (R. Blumauer, personal

communication, September 27, 2021). There is a skull, from the New Hebrides, with the inventory number 42.808 (Post 12, 1891), collected by Andreas Reischek sen., which has similar characteristics as the mummy skull 5 "The Clay Face". Also the facial skull was covered with clay and a thumb-thick hole was punched in each eye. In addition, the face painting is similar: black stripes cover the forehead with a thick black stripe extending across the forehead, ending with the eyebrows. One stripe passes through the zygomatic bone and the maxilla, and another stripe passes across the maxilla. The coloration of the mouth region was omitted. However, there is one difference in the painting of the skull: The skull from the World Museum has a black coloration across the eye area that looks like an eye mask. This form of painting is not found on the mummy skull 5 "The clay face".

Flower (1882) describes that head from the New Hebrides show that the face up to the forehead was covered with a clay mixture and some facial features seemed to have reconstructed. These include the brow ridges, the nose, the ear muscles and also eyes were modelled as a deep hole. He further describes, that the skulls were painted with a dark reddish-brown to almost black color. Broad bands were painted on the face as part of the process. This description of the clay features, the colorations and the intentional cranial modification match with the mummy skull 5 "The clay face" (Figure 36 A, B, C).

According to this, an assignment of the mummy skull 5 "The clay face" to New Hebrides is very likely.



Figure 36. Representation of the face mask and painting of the New Hebridean mummy skull 5 "The clay face" (A-B) and comparison of left sagittal illustration by Rüdinger (1888) (C). Both skulls show typical New Hebrides circumferential deformation.

In total 12 individuals or 50% of all 24 investigated skulls/heads came from Egypt, almost as many could be assigned to the origin Peru (11 or 46%) and only one possibly originates from the New Hebrides.

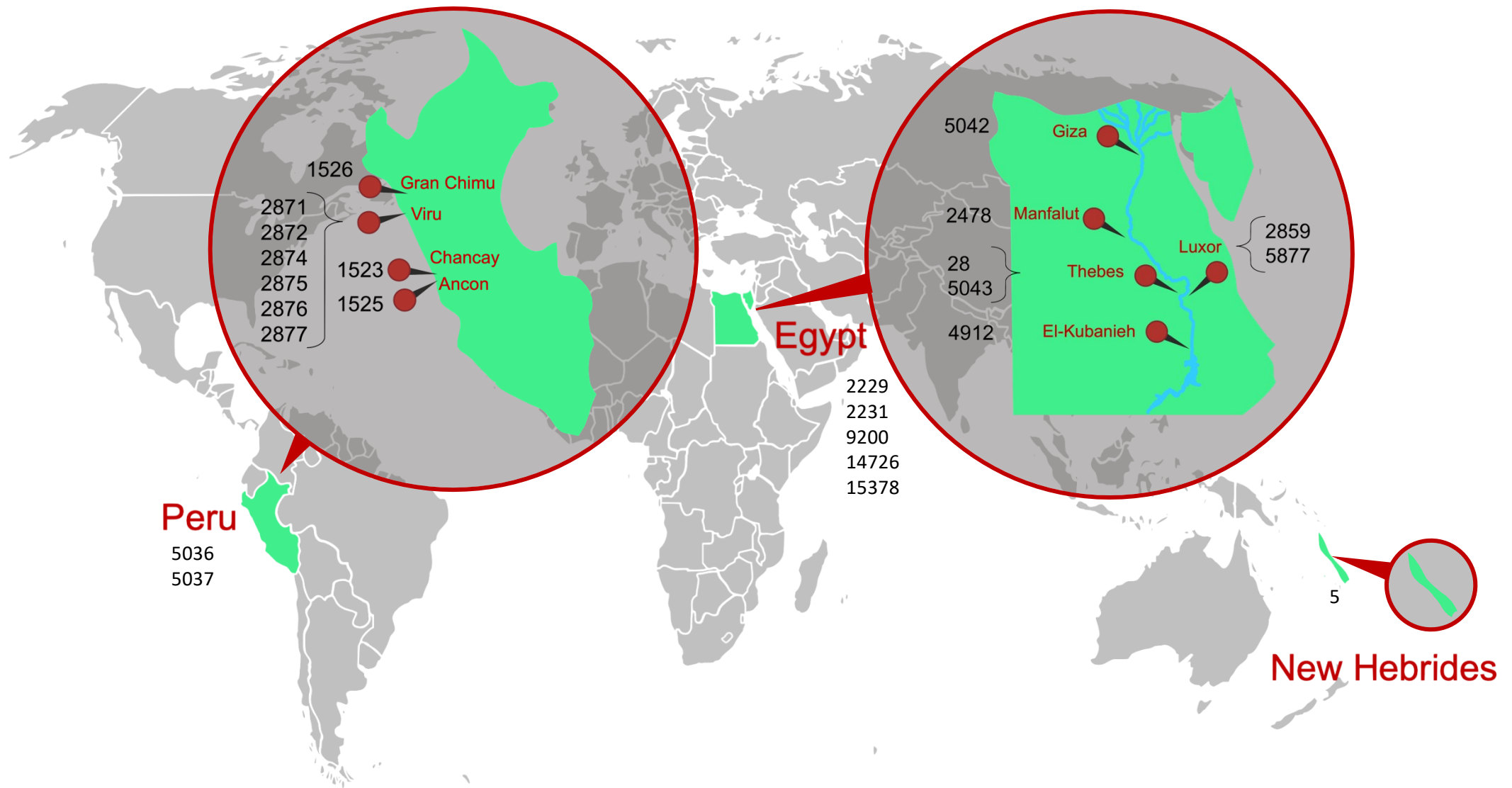


Figure 37. Distribution map of inventory numbers by origin.

(Free Editable Worldmap for Powerpoint, n.d.; edited with Microsoft Power Point Version 16.54 and Adobe Fresco 2.7.9. by Liesa Geppner). Those inventory numbers that could not be assigned to a specific region were listed next to the respective country name.

3.4 Sex and age

Table 25 gives an overview of the place of origin of the 24 individuals as well as the sex and age group to which they were assigned.

In total, seven female, 15 male and two undetermined skulls/heads were recorded. The designation "undetermined or not determinable" refers to the two juveniles 1523 and 28 with ages at death 6-7 and 12-13 respectively that cannot be morphologically assigned to any sex, since sexual dimorphism tends only to be recognizable on bony features of the skull during adolescence (at around 15 years) (Buikstra & Ubelaker, 1994). The inventory numbers 9200 (between 18 and 20 years) and 2876 (ca. 15 years) also belong to the age group of adolescent individuals, but already with a more advanced age. Therefore, a sex estimation of these skulls was possible.

Figure 38 shows a graphical representation of the number of skulls separated by origin and sex. In order to get an overview of the frequency of skulls within each country and divided by gender and age group, Figure 39 was created. Among the Egyptians, all five men are of middle adult age, while the women are represented by all age groups (3 young adult, 1 adolescent, 1 middle adult and 1 old adult women). Among the Peruvians, it is the men who are represented in many different age groups (1 adolescent, 3 young adult, 4 middle adult and 1 old adult man). The only female Peruvian individual belongs to the middle adult age group. The only male New Hebrides can be included in the young adult age group. Unfortunately, the amount of data is far too small to make a statistical statement about this.

Not all individuals could be clearly assigned to an age group with the help of the cranial sutures alone. In some very young individuals, the age was determined with the help of the tooth eruption or tooth root development, and in some ambiguous findings, the tooth and joint abrasion or tooth preservation was also included in addition to the cranial sutures. This is summarized in Table 25.

Table 25. Inventory numbers with classification into origin, sex and age category.

The term "n.d." refers to those individuals who could not be assigned to a sex due to their young age.

Origin	Inv. No.	Sex	Age group	Age estimation acc. to
Egyptian	28	n.d.	Adolescent	Tooth eruption
	2229	Female	Young adult	Cranial sutures + tooth abrasion
	2231	Female	Young adult	Cranial sutures
	2478	Male	Middle adult	Cranial sutures
	2859	Female	Old adult	Cranial sutures + tooth abrasion
	4912	Male	Middle adult	Cranial sutures + tooth abrasion
	5042	Female	Middle adult	Cranial sutures
	5043	Male	Middle adult	Cranial sutures + tooth abrasion
	5877	Male	Middle adult	Cranial sutures + tooth abrasion
	9200	Female	Adolescent	Tooth eruption
	14726	Male	Middle adult	Cranial sutures + tooth abrasion
	15378	Female	Young adult	Tooth root development
Peruvian	1523	n.d.	Child	Tooth eruption
	1525	Male	Young adult	Cranial sutures + tooth/ joint abrasion
	1526	Female	Middle adult	Cranial sutures + tooth/ joint abrasion
	2871	Male	Young adult	Cranial sutures
	2872	Male	Old adult	Cranial sutures + tooth preservation
	2874	Male	Middle adult	Cranial sutures + tooth preservation
	2875	Male	Middle adult	Cranial sutures
	2876	Male	Adolescent	Tooth root development
	2877	Male	Middle adult	Cranial sutures + tooth abrasion
	5036	Male	Young adult	Cranial sutures
	5037	Male	Middle adult	Cranial sutures + joint abrasion
New Hebridean	5	Male	Young adult	Tooth abrasion

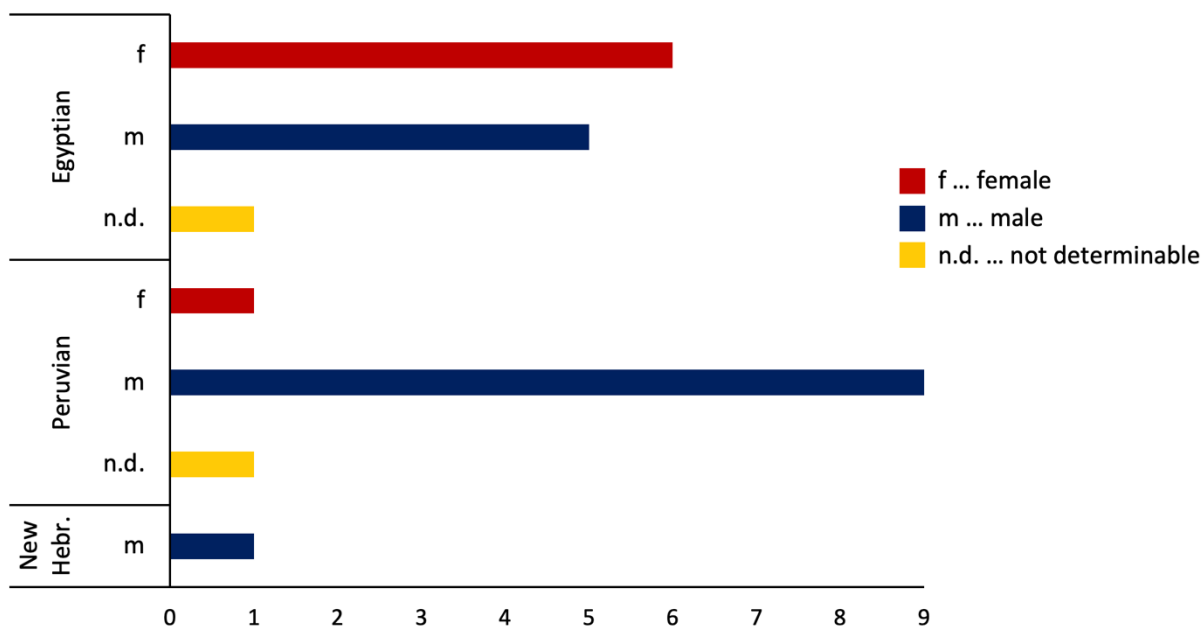


Figure 38. Number of skulls separated by origin and sex.

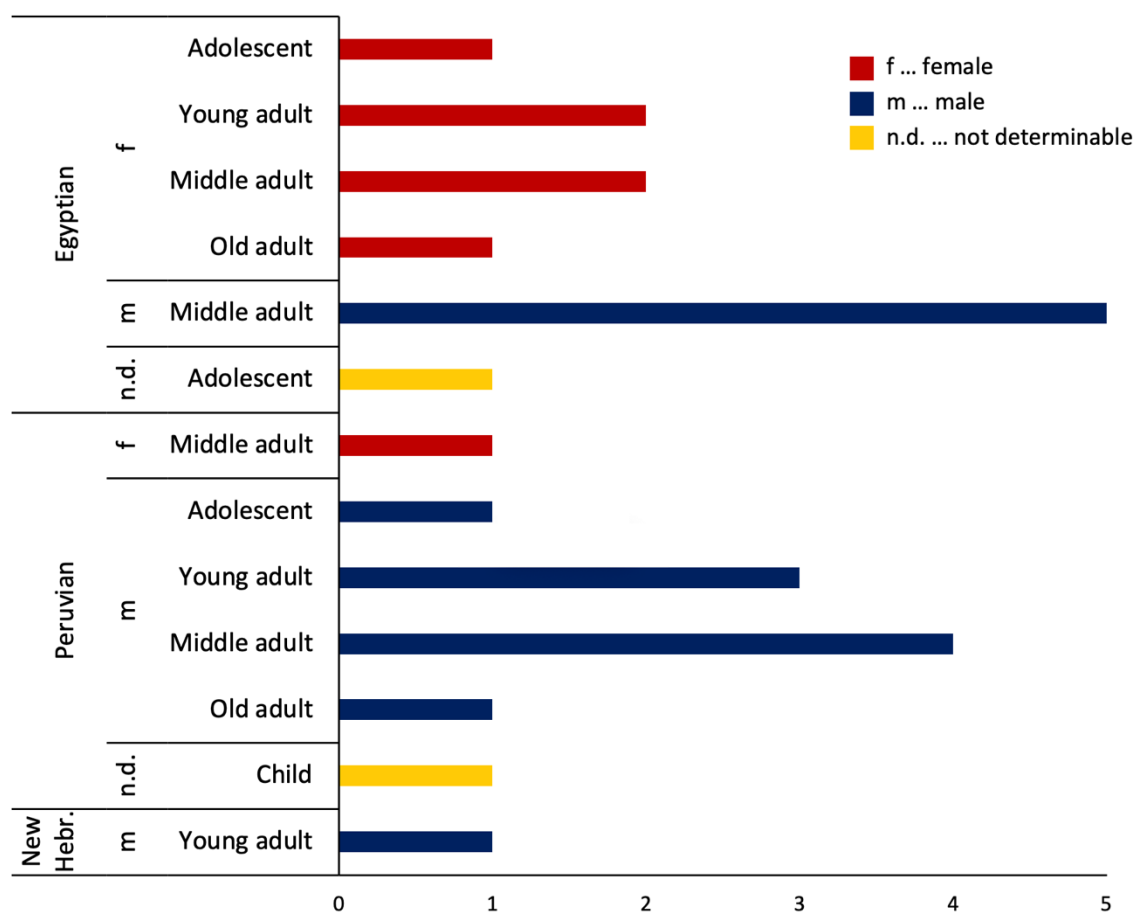


Figure 39. Number of skulls separated by origin, sex and age group.

3.5 Dental status

This chapter differentiates between Egyptians and Peruvians in order to present the results, but this does not provide a representative sample of the respective case studies. This is because single individuals from different times and different cultures are involved. For this reason, only frequencies and average values are described.

Table 26 gives an overview of the health status of the teeth. The table shows the number of teeth lost antemortem, compared to those lost postmortem and those still in the jaw. Furthermore, the abrasion degree is given, which is classified into three categories: slight, medium and high. In addition, the number of carious teeth, abscesses and teeth with calculus (including the degree of severity) is given.

For the following analysis and graphical representations only those individuals were included in which both mandible and maxilla were completely present. Therefore, the individuals with the inventory numbers: 28, 2229, 2231, 1523, 2871 were excluded from further analyses (Table 26, existing bone part is marked with Mx = maxilla or Md = mandible).

A more detailed comparison of the degree of abrasion with the age groups shows that the frequencies of the abrasion categories is similar in Egypt as compared to Peru (Figure 40). The degree of dental abrasion as well as ante mortem tooth loss tends to be more severe with older the age of death, with the exception of one young adult Peruvian (5036) with severe abrasion.

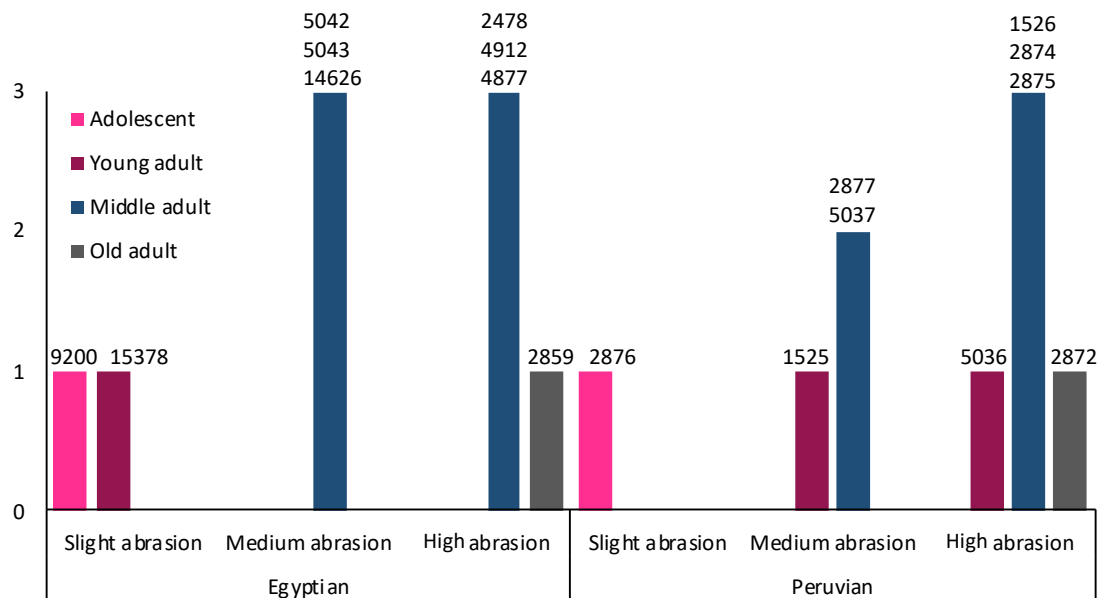


Figure 40. Frequency of slight, middle and high abrasion divided by origin and age groups. The respective inventory numbers are listed above the bar. Only those individuals are included where both mandibles and maxillae are present.

The frequency of caries and abscesses differs between the two countries of origin, Peru and Egypt (Figure 41). In terms of numbers, Peruvians tend to show a higher number of caries (on average 2,4 versus 1,9 respectively), abscesses (on average 1,9 versus 1,3 respectively) and ante mortem tooth loss (on average 5,4 versus 3 respectively) than Egyptians. A correlation between the frequencies of caries and abscesses cannot be seen in this example. However, it is noticeable that almost all individuals with abscesses (7 out of 10) show high abrasion. The remaining individuals with abscesses present medium abrasion. While there are three individuals among the Egyptians who have neither caries nor abscesses, all individuals among the Peruvians are affected by caries and/or inflammatory processes on the bone.

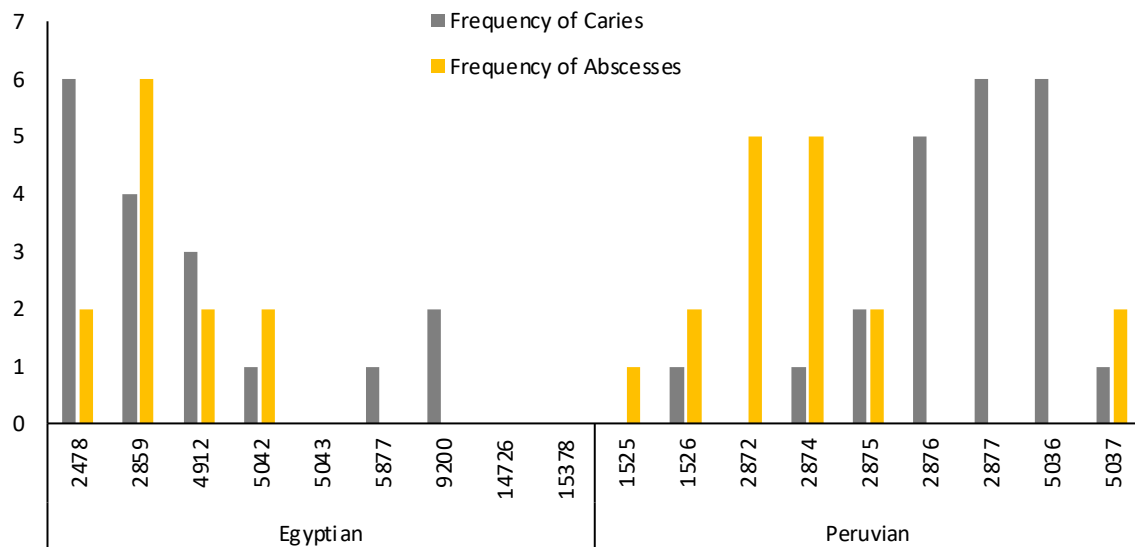


Figure 41. Number of caries and abscesses per individual divided by their origin. Only those individuals are included where both mandibles and maxillae are present.

In total, Peruvians have also more antemortem lost teeth than Egyptians. There are 54 antemortem lost teeth in Peruvians versus 29 antemortem lost teeth in Egyptians (Figure 42). Adolescents and young adults have low levels of antemortem tooth loss (total of 3 individuals with an average of 1.6 ante mortem lost teeth), while the middle adult group (total of 12 individuals with an average of 4.4 ante mortem lost teeth) and the old adult group (total of 2 individuals with an average of 7.5 ante mortem lost teeth) show a lot of antemortem lost teeth.

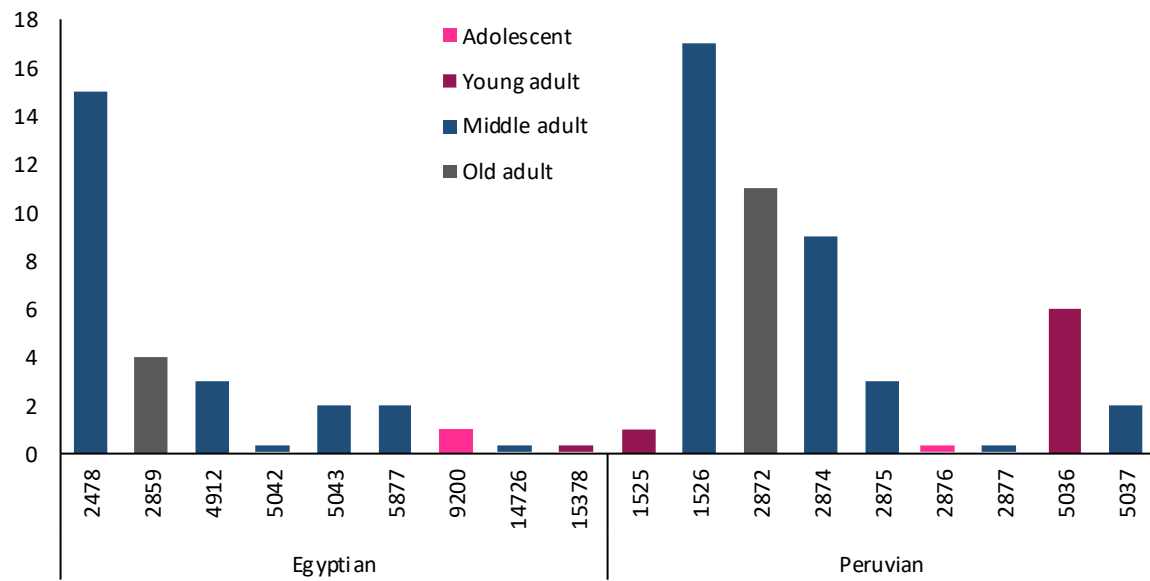


Figure 42. Frequency of antemortem lost teeth divided by origin, inventory number and age group. Only those individuals are included where both mandibles and maxillae are present.

Table 26. Summary of the dental status for all skulls

Origin	Inv. no.	Tooth inventory Number of...			Abrasion category	Number of carious teeth	Number of abscesses	Calculus	
		...ante-mortem lost teeth	...post-mortem lost teeth	...teeth still in the alveoli				Number of teeth with calculus	Degree of severity
Egyptian	28	0	14	2 ^{Md}	m	0	0	0	
	2229	0	12/4	4 ^{Mx}	s	0	0	0	
	2231	2	14/1	0 ^{Mx}	n.d.	n.d.	2	n.d.	
	2478	15	0	17	h	6	2	n.o.	
	2859	4	23/9	5	h	4	6	6	1-3
	4912	3	6/1	7	h	3	2	1	1
	5042	0	14/2	2	m	1	2	1	1
	5043	2	0	30	m	0	0	n.o.	
	5877	2	5/2	25	h	1	0	n.o.	
	9200	1	0	31	s	2	0	n.o.	
	14726	0	0	32	m	0	0	n.o.	
	15378	0	0	32	s	0	0	n.o.	
Peruvian	1523	0	6	6 ^{Mx}	n.d.	0	0	0	
	1525	1	24/3	7	m	0	1	7	1
	1526	17	10	5	h	1	2	5	1
	2871	5	9	2 ^{Mx}	h	0	1	0	
	2872	11	20/2	1	h	0	5	1	1
	2874	9	18/1	5	h	1	5	4	1-3
	2875	3	14/2	15	h	2	2	11	1-2
	2876	0	19	13	s	5	0	4	1
	2877	0	4/2	28	m	6	0	17	1-2
	5036	6	10	16	h	6	0	8	1-2
	5037	2	15/1	15	m	1	2	15	1-3
New Hebr.	5	1	7	24	m	0	0	n.o.	

Nr.
/

The inventory numbers of those mummies, where the mouth part was at least partially wrapped in embalming material or soft tissue are highlighted in green.

The number after the sign "/" for teeth lost postmortem indicates the number of teeth broken off. This was the case, if so much of the tooth is damaged that abrasion and caries could not be determined. Otherwise, they were included in "teeth still in the alveoli".

Mx, Md The letters after the numbers in "teeth still in the alveoli" indicate when only part of the jaw was present. "Mx" indicates "only maxilla available" and "Md" indicates "only mandible available".

3.6 Intentional cranial modification and Trepanation

3.6.1 Intentional cranial modification

The 10 Peruvian skulls in Table 27 show tabular intentional cranial modification. Eight out of the 10 individuals exhibit symmetric bilobed bulging at the parietal bone, resulting in a broadening of the posterior part of the skull. The pressure on the baby's head must probably have been mainly applied at the squamous portion of the occipital or the lambda bones, resulting in a depressed occipital bone. For 7 out of 10 tabular intentional modified crania, the plane of pressure is perpendicular (90°) to the transverse plane. Also, the anterior part of 8 out of 10 tabular modified crania shows some form of deformation. There is only one Peruvian skull (2875) that shows no intentional cranial modification. This is curious, since all other 10 individuals reported to have been collected in Peru do show intentional cranial modification.

There is also intentional cranial modification assessable in two Egyptian skulls (Table 27). For the skull 2229, unfortunately, the most important part for assessment of the type of cranial modification is missing: the posterior part of the skull with the parietal bones and the occipital bone. However, there is an impression visible on the frontal bone (just above the glabella) which is accompanied by a different coloring (lighter stripe) (Figure 43). The mummified head 9200 shows mild depression and an asymmetric deformation at the occipital bone. However, no deformation of the frontal bone is visible. Therefore, it cannot be determined with certainty that these are intentional cranial modifications (Figure 44).

Table 27 shows, that the posterior part of the New Hebridean mummy head 5 "The Clay Face" is very round and shows no depression, but a very elongated skull. However, the frontal bone is very flat (Figure 45). It is possible that this is a circumferential deformation, where pressure has been applied laterally on the frontal bone to elongate the skull. However, no impressions of binding are visible.

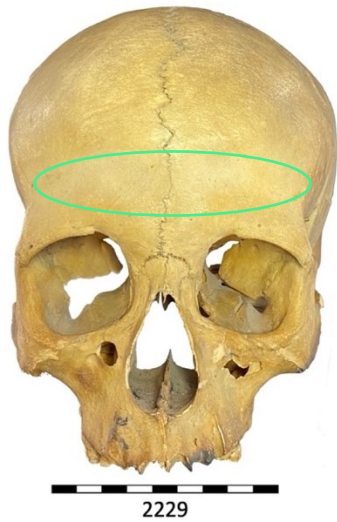


Figure 43. Green circle indicates impression marks at the frontal bone of the Egyptian skull 2229.



A



B

Figure 44. Posterior (A) and superior (B) view of the Egyptian mummified head 9200 shows asymmetric deformation and mild depression at the right side.



Figure 45. Left sagittal picture of the mummified head 5 from the New Hebrides shows depressed frontal bone and the elongated skull.

The following figures (Figure 46 to Figure 48) show a comparison of tabular, circumferential and not modified skulls. Unfortunately, this visualization could only be made with those skulls that had CT scans. Even though not enough scanned skulls are available for more image comparisons, the eight available scans were nevertheless used to try to show visual comparisons of the cranial modifications.

Figure 46 shows comparison of the New Hebridean skull with the number 5 "The Clay Face" and the Peruvian skull 2876 that show the different kinds of intentional cranial modification. Mummy 2876 shows a flattened occipital bone that indicates a tabular deformation and the skull from the mummy 5 is very elongated to the back, as also occurs with circumferential deformations.

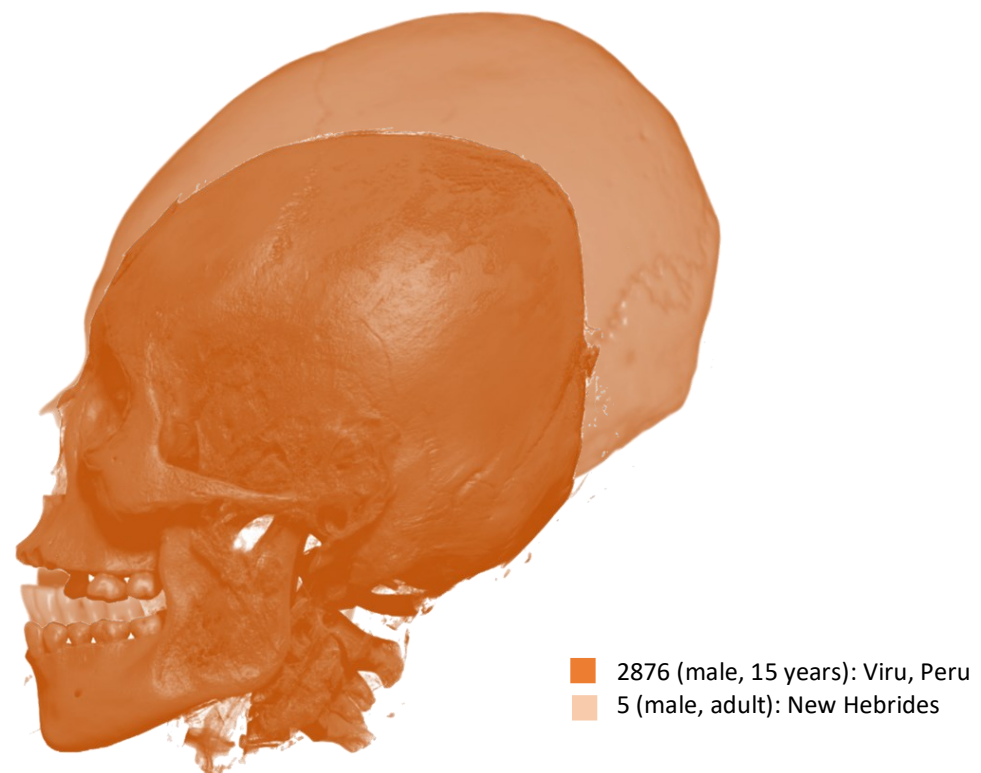


Figure 46. 3D Visualization shows deformation differences of the New Hebridean skull with the number 5 "The Clay Face" in comparison to the Peruvian skull 2876.

The skulls were scaled to the same size and then aligned in the same place at the nasal landmark and at the zygomatic bone. Deformed skulls are colored in orange. The key next to the illustrations explains which color represents which individual.

Intentional cranial modification comparison of three young adult female skulls and one middle adult male skull is shown in Figure 47. The mummy 9200 shows a slightly deformed and flattened area above the lambda region, 15378 and 2478 show no intentional cranial modification and the mummy with the inventory number 2876 does show extreme flattened frontal bone and depressed occipital bone. Skull 2478 has an almost identical skull shape as skull 15378. However, it can be seen that 2478 is a male skull, as it has a less vertical forehead and a rougher surface of the occipital region than the other two Egyptian female skulls.

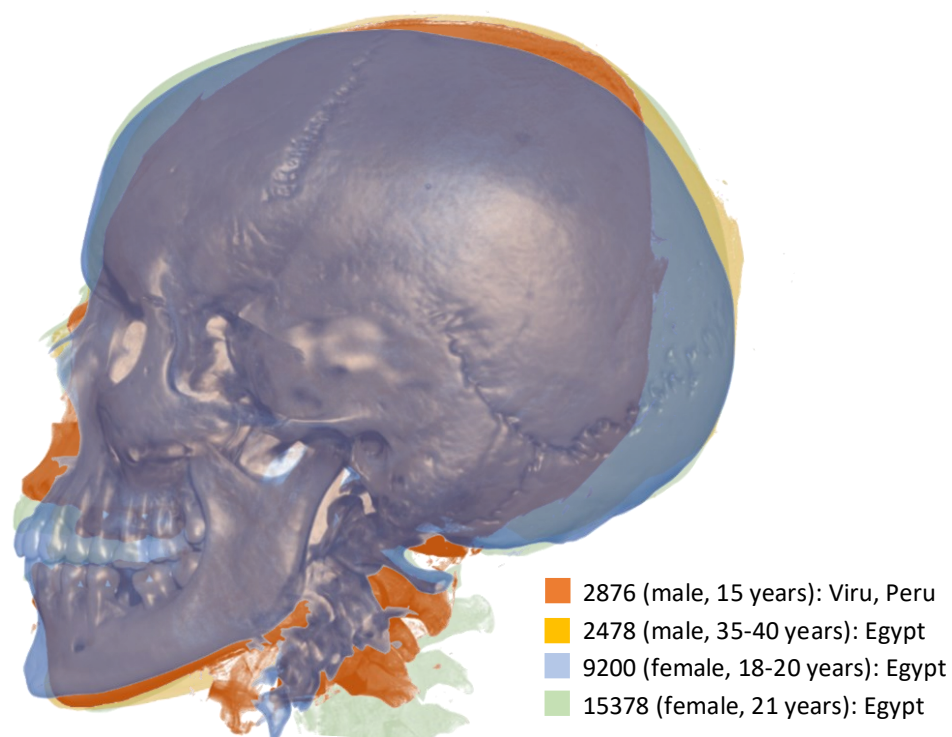


Figure 47. 3D Visualization shows deformation differences of the Peruvian skull 2876 and the Egyptian skulls 9200 and 15378.

The skulls were all scaled at the same size and then aligned in the same place at the nasal landmark and at the zygomatic bone. Deformed skull is colored in orange. Undeformed skulls are colored in yellow, blue and green. Key next to the illustrations explains which color represents which individual.

Deformation comparison of four different adult skulls is shown in Figure 48. Mummies 5043, 5877 and 14726 show no intentional cranial modification. It is clearly visible that the skull of mummy 5 has a much larger skull, which is elongated towards the back. The mummy 5043 is a bit smaller than the other three skulls, this may be because that is a female skull while all the others are male.

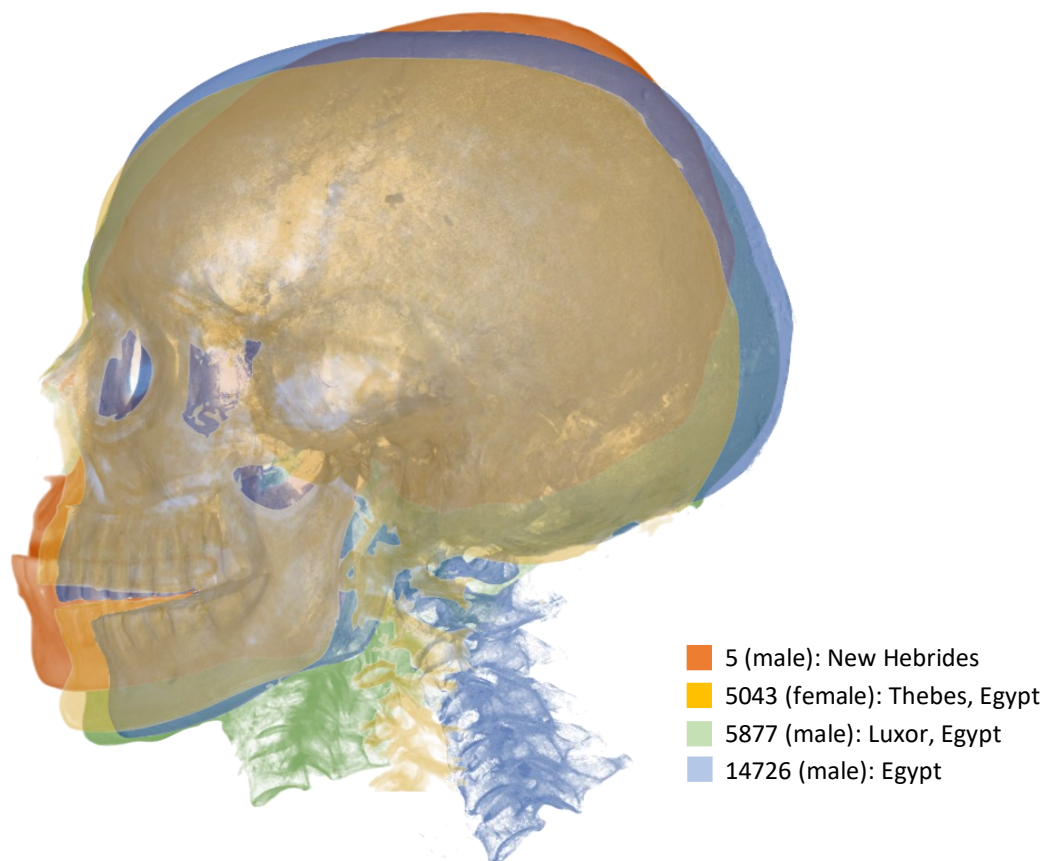


Figure 48. 3D Visualization shows deformation differences of the three not deformed Egyptian mummy skulls 5043, 5877 and 14726 and the deformed Peruvian mummy skull with the number 5 "The Clay Face". The skulls were all scaled at the same size and then aligned in the same place at the nasal landmark and at the zygomatic bone. Deformed skull is colored in orange. Undeformed skulls are colored in yellow, green and blue. Key next to the illustrations explains which color represents which individual.

Table 27. Description of intentional cranial modification, verified on the Egyptian, Peruvian and New Hebridean skulls.
Skulls not mentioned in this table showed no signs of intentional cranial modification.

	Inventory numbers							
	Egyptian		Peruvian					
Intentional cranial modification	2229	9200	1523	1525	1526	2871	2872	
General aspects	General category	Tabular	Tabular	Tabular	Tabular	Tabular	Tabular	
	Form (acc. to Neumanm, 1942)	N.d.	Occipital	Fronto-Occipital	Lambdoid	Fronto-Occipital	Fronto-Occipital	
	Elevation at bregma	No	No	No	No	No	No	
	Elevation at lambda	No	No	No	No	No	No	
	Post-coronal depression	No	No	No	No	No	No	
	Depression at lambda	No	No	No	No	No	No	
	Sagittal elevation	No	No	No	No	No	No	
Posterior aspects	Cranial deformation present	N.d.	Yes	Yes	Yes	Yes	Yes	
	Degree of deformation		Moderate	Moderate	Moderate	Moderate	Mild	
	Symmetrical reshaping?		No	Yes	No, right side more deformed	Yes	No right side more deformed	Yes
	Pressure was centered at		Squamous portion of occipital	Lambda	Squamous portion of occipital	Squamous portion of occipital	Lambda	Lambda
	Plane of pressure in relationship to transverse plane		Perpendicular (90°)	Obtuse (>90°)	Obtuse (>90°)	Obtuse (>90°)	Perpendicular (90°)	Perpendicular (90°)
	Pad location		Asymmetrically right	Asymmetrically right	Midline	Midline	Midline	Midline
	Impression of bindings visible		No	No	No	No	No	No
Anterior aspects	Cranial deformation present	Other	No	Tabular	Tabular	Tabular	Tabular	
	Degree of deformation	N.d.		Mild	Mild	Moderate	Moderate	
	Symmetrical reshaping?	Yes		Yes	Yes	Yes	Yes	
	Pressure was centered at			High, near coronal suture	Low, near/below frontal boss	High, near the coronal suture	Low, near/below frontal boss	Low, near/below frontal boss
	Pad location			Midline	Midline	Midline	Midline	Midline
	Impression of binding visible	Yes		No	No	No	No	No

	Inventory number					
Intentional cranial modification	Peruvian					New Hebridean
Inventory number	2874	2876	2877	5036	5037	5
General aspects	General category	Tabular	Tabular	Tabular	Tabular	Circumferential
	Form (acc. to Neumanm, 1942)	Fronto-Occipital	Fronto-Occipital	Fronto-Occipital	Lambdoid	Loaf-shaped
	Elevation at bregma	Yes	No	No	No	No
	Elevation at lambda	No	No	No	No	No
	Post-coronal depression	No	No	No	No	No
	Depression at lambda	No	Yes	Yes	Yes	No
	Sagittal elevation	Yes	No	No	No	Yes (slightly)
Posterior aspects	Cranial deformation present	Yes	Yes	Yes	Yes	No
	Degree of deformation	Extreme	Extreme	Extreme	Mild	
	Symmetrical reshaping?	Yes	Yes	Yes	Yes	
	Pressure was centered at	Lambda	Squamous portion of occipital	Squamous portion of occipital	Lambda	
	Plane of pressure in relationship to transverse plane	Perpendicular (90°)	Perpendicular (90°)	Perpendicular (90°)	Perpendicular (90°)	
	Pad location	Midline	Asymmetrically left	Asymmetrically left	Midline	
	Impression of bindings visible	No	No	No	No	
Anterior aspects	Cranial deformation present	Tabular	Tabular	Tabular	No	Yes
	Degree of deformation	Moderate	Moderate	Moderate		Mild
	Symmetrical reshaping?	No right side more deformed	Yes	Yes		Yes
	Pressure was centered at	Low, near/below frontal boss	Middle frontal	Middle frontal		Lower frontal
	Pad location	Asymmetrically left	Midline	Midline		Midline
	Impression of binding visible	No	No	No		No

3.6.2 Trepanation

Only one of the 24 skulls examined had a trepanation hole. Table 28 describes the big trepanation at the skull 2871 from Peru. The oval hole is located at the left parietal bone and has a length of 27 mm and a width of 14 mm (Figure 49). Due to the very rounded edges and the thickening of the bone in the area of the trepanation, it can be concluded that this lesion had already healed a long time before death, although it did not reach closure of the opening.

Table 28. Trepanation recording form coded by location, certainty of identification, technique, evidence of healing and size of the removed section for skull 2871.

Trepanation	
1. Location: Bone	Parietal
2. Location: Site	Left
3. Certainty	Clear evidence of trepanation
4. Technique	Grooving (oval)
5. Healing	Definite evidence of healing
6. max. Dimension (mm)	27
7. min. Dimension (mm)	14



Figure 49. Trepanation at the left parietal bone of the Peruvian skull 2871.

3.7 Palaeopathology

3.7.1 Cribra orbitalia, Porotic hyperostosis and Osteoarthritis

The three most common diseases observed among the skulls studied herein are presented in Table 29. Ten out of 24 skulls show porous lesions in the orbitae with healing signs visible in only one case. Porotic hyperostosis even occurred in ten individuals with partly very strong expressions and in some cases large healing areas. Figure 51 shows manifestations of cribra orbitalia and porotic hyperostosis in some of these individuals.

Osteoarthritis was experienced in 12 out of 18 individuals in which the trait could be investigated (Figure 52).

Although the Peruvian and the Egyptian skulls described herein do not by any means represent true groups, it nevertheless is interesting to note that the three palaeopathologies analyzed tend to be more common among Peruvians than Egyptians (Figure 50): $6/11 = 55\%$ versus $4/12 = 33\%$ for cribra orbitalia, $8/11 = 73\%$ versus $1/10 = 10\%$ for porotic hyperostosis and $7/10 = 70\%$ versus $4/7 = 57\%$ for osteoarthritis.

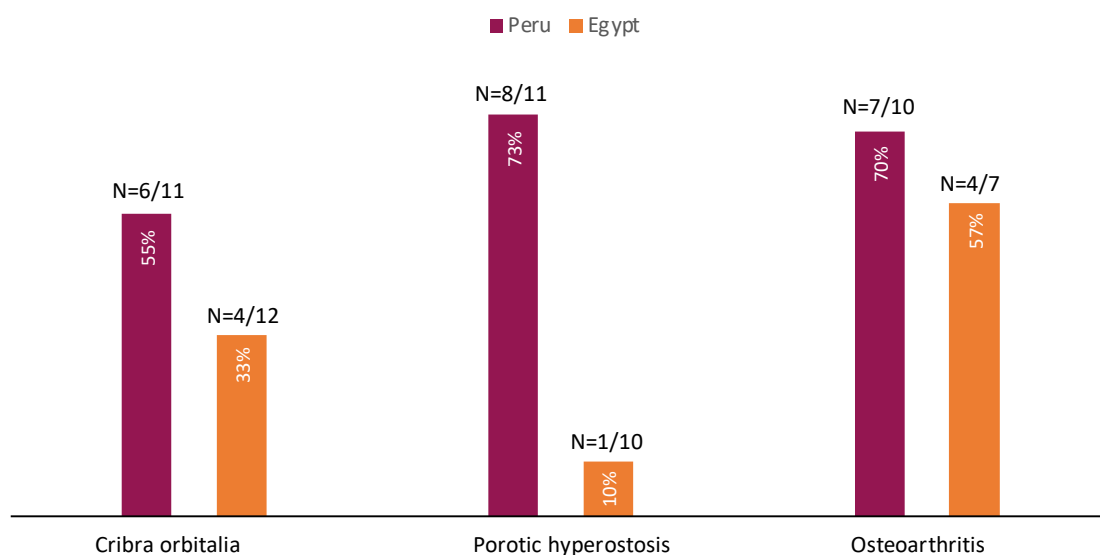


Figure 50. Frequency of the three most common diseases among Egyptian and Peruvian skulls/heads.

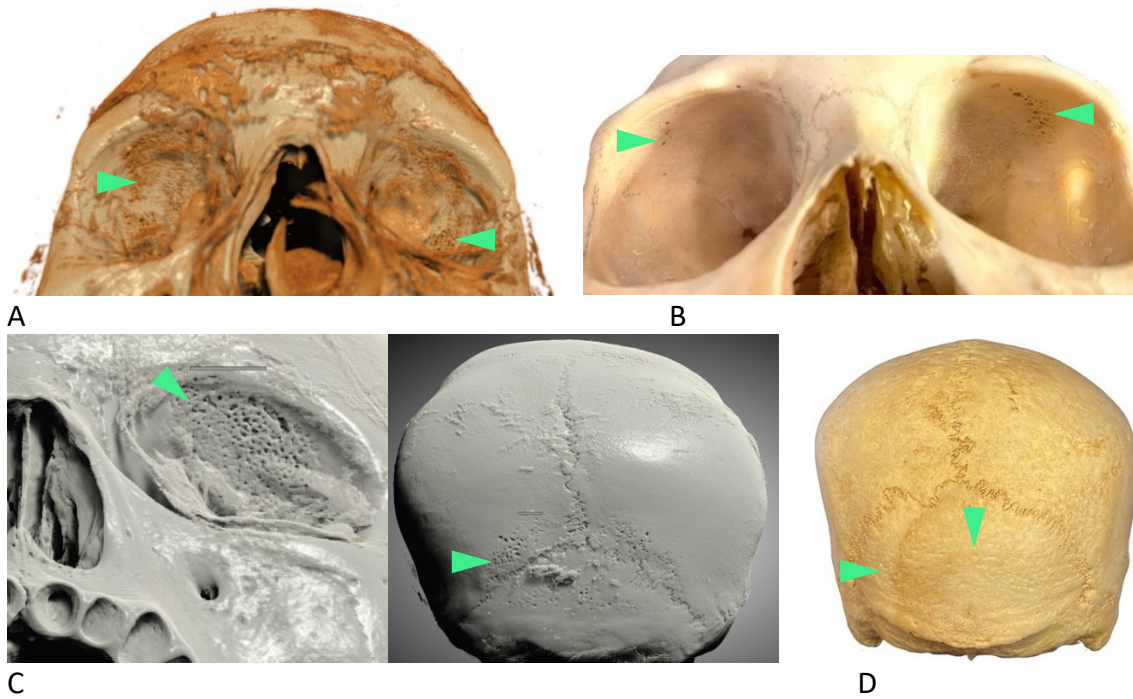


Figure 51. Cribra orbitalia (A,B,C) and porotic hyperostosis (D) of the following skulls: μ -Ct of Egyptian mummified head 14276 (A), picture of Egyptian mummified head 1526 (B), μ -CT of Peruvian skull 2876 (C) and picture of Peruvian skull 5036 (D).

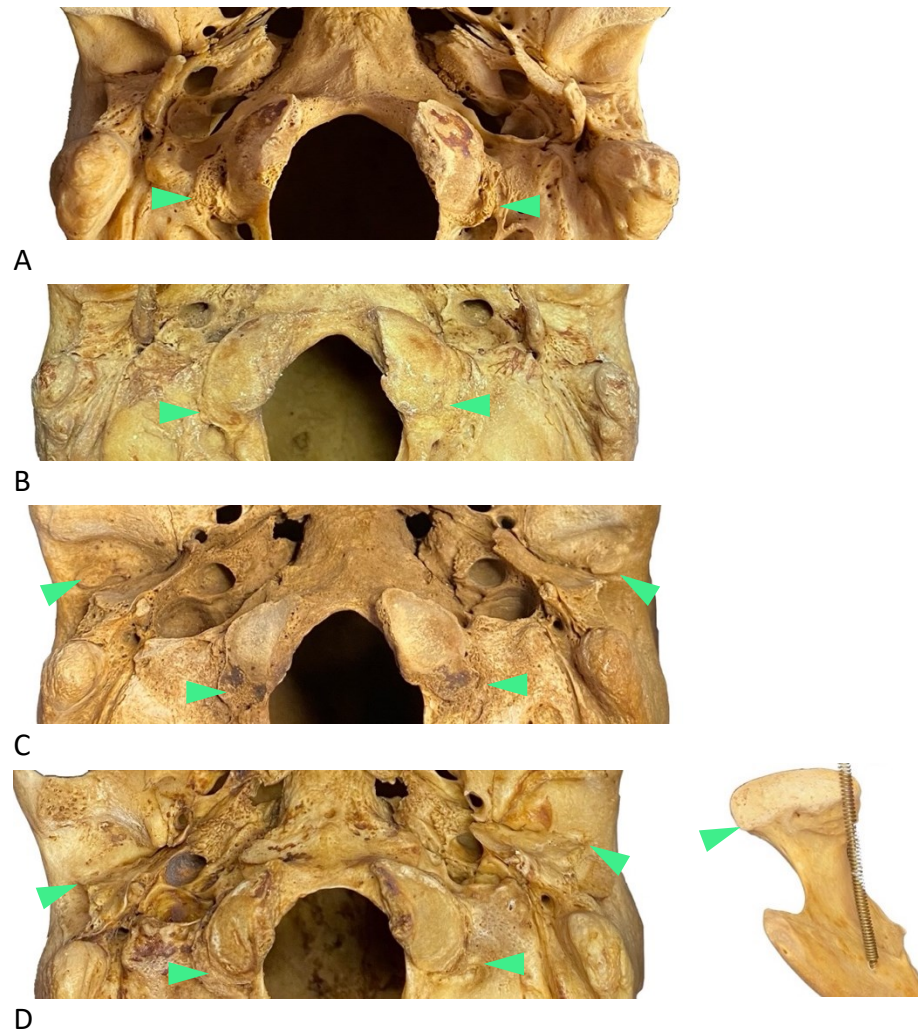


Figure 52. Osteoarthritic changes at the occipital condyles and/or the temporomandibular joint of the following Egyptian skulls: 2859 (A), 2875 (B) and 5042 (C) and the one Peruvian skull 4912 (D).

Table 29. Overview of the three most common diseases observed on the skulls/heads.

The temporomandibular joint is marked as not observable (n.o.) when the mandibular condyle is tightly fixed in the mandibular fossa and the two bones could not be separated.

For severity 0 means absence of lesion and 4 indicates marked development of trabecular part of the bone surface. Healing is described with numbers from 1 to 4, with 1 meaning no healing activity, and 4 indicating fully healed lesions.

Origin	Inv. no.	Degree of Expression of Cribra orbitalia		Degree of Expression of Porotic hyperostosis		Osteoarthritis	
		Severity	Healing	Severity	Healing	Occipital condyles	Tempo-mandibular joint
Egyptian	28	2	1	n.o.	n.o.	yes	no
	2229	1	1	n.d.	n.d.	n.d.	n.d.
	2231	0		0		no	no
	2478	1	3	0		no	no
	2859	0		0		yes	no
	4912	0		0		yes	yes
	5042	0		0		yes	yes
	5043	0		0		no	no
	5877	0		0		n.o.	n.o.
	9200	0		1	3	n.o.	n.o.
	14726	2	2	0		n.o.	n.o.
	15378	0		0		n.o.	n.o.
Peruvian	1523	1	1	1	1	no	no
	1525	1	1	2	2	yes	no
	1526	1	1	1	1	yes	yes
	2871	0		0		yes	no
	2872	0		0		no	no
	2874	0		3	3	yes	n.o.
	2875	1	1	3	2	yes	no
	2876	3	1	3	2	n.o.	n.o.
	2877	0		0		no	no
	5036	0		1	1	yes	no
	5037	1	1	2	2	yes	yes
New Hebridean	5	0		1	1	yes	n.o.

3.7.2 Exostosis

Two Peruvian skulls, with the inventory number 2872 and 5037, showed bilateral auditory exostosis with an already very small and constricted external acoustic meatus (Figure 53). The auditory canal, in the case of individual 5037, is already almost completely closed by bone attachments and shows new bone formation around the auditory entrance. This ossification in the auditory canal was only found in Peruvian skulls.

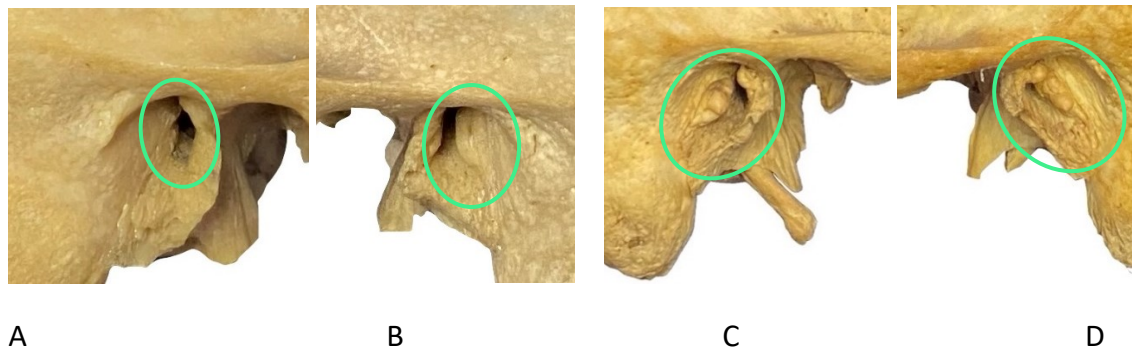


Figure 53. Picture of the right (A) and left (B) external auditory meatus of the Peruvian skull 2872 and of the right (C) and left (D) external auditory meatus of the Peruvian skull 5037 shows bony overgrowth.

3.7.3 Trauma

Regarding trauma, 1/11 Peruvian, 3/12 Egyptian and no New Hebridean skulls/ heads shows evidence of trauma.

Externally, when looking at the Egyptian mummified head 2478, there is no evidence to suggest a head trauma. Only when looking at the μ -CT data and after the overlying material on the bone was removed by changing the contrast, an approximate 1cm x 1cm possible perimortem trauma became visible (Figure 54). The fracture is round and has sharp edges, in the middle a smaller almost circular area is depressed and the lateral bony edges are cracked. The fracture is larger on the inside of the skull than on the outside. In the enlargement of Figure 55, even the two branches of the meningeal artery (red) intersect with the fracture margins (yellow) can be seen.

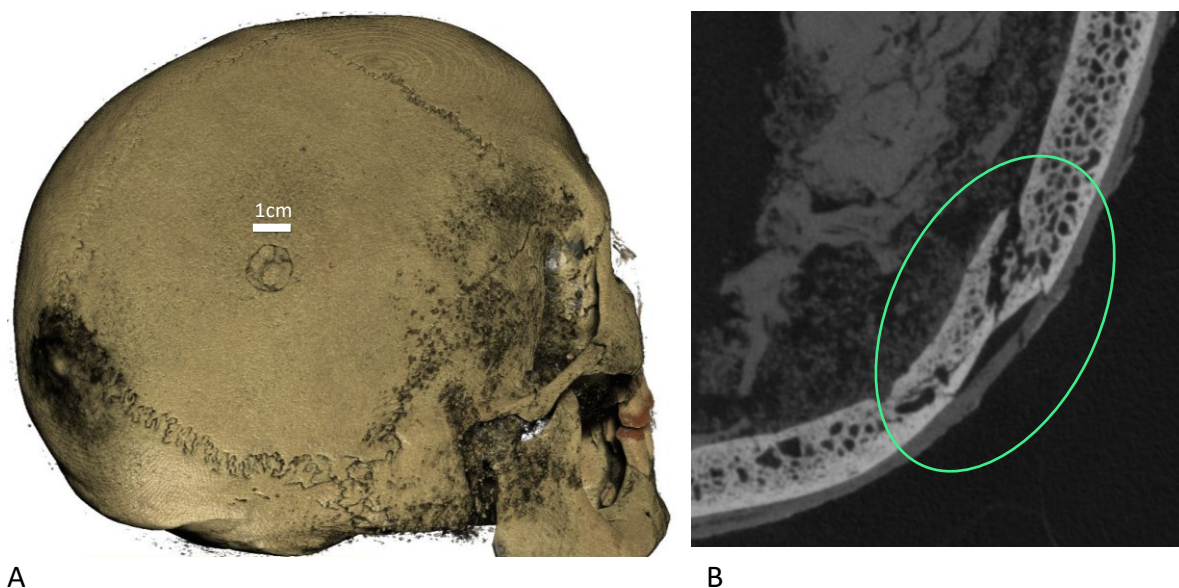


Figure 54. 3D visualization (A) of the Egyptian mummified head 2478 shows the trauma and the 2D sectional view (B) indicates the fracture and intact outer skin layer (green circle).

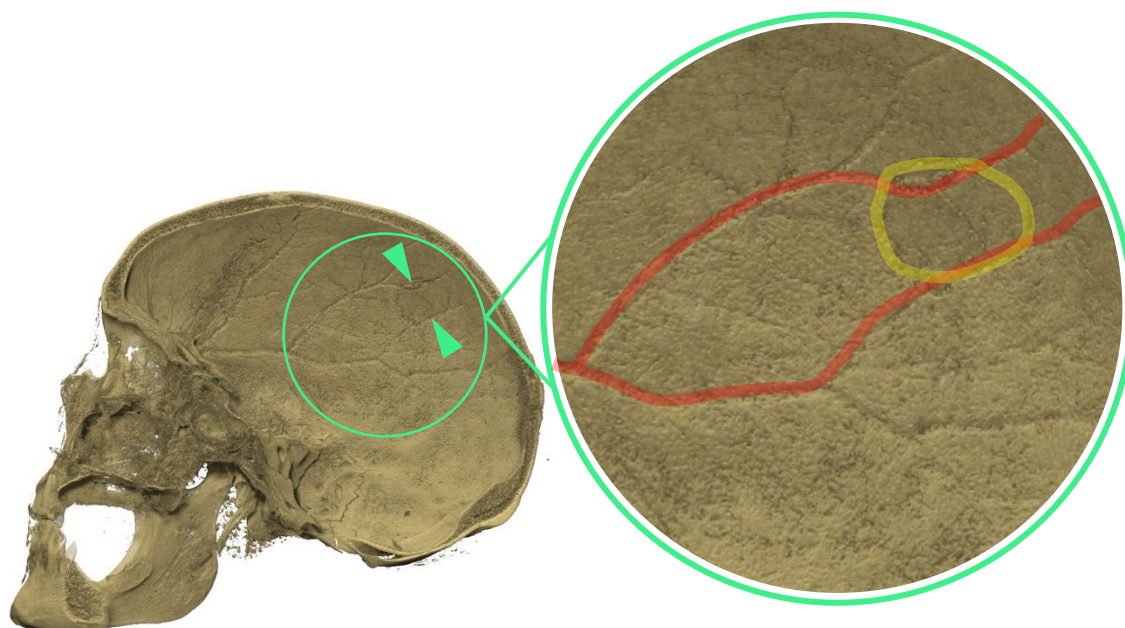


Figure 55. 3D visualization and enlargement of the internal cranial vault of the Egyptian mummified head 2478 shows the branches of the middle meningeal artery in red and the fracture lines in yellow. The green arrows also indicate the fracture lines.

The Peruvian skull 2871 has a severe partially healed trauma. The zygomatic process of the temporal bone is broken on both sides (Figure 56), but healed, with small overlaps. The fracture is not symmetrical on both sides. On the left side, the broken piece of bone is slightly more skewed and more displaced than on the right side. The left broken

zygomatic bone shows a fracture at the temporozygomatic suture, at the zygomatic process and a third fracture at the posterior end of the zygomatic process. At the right side, only one fraction at the zygomatic process is visible.

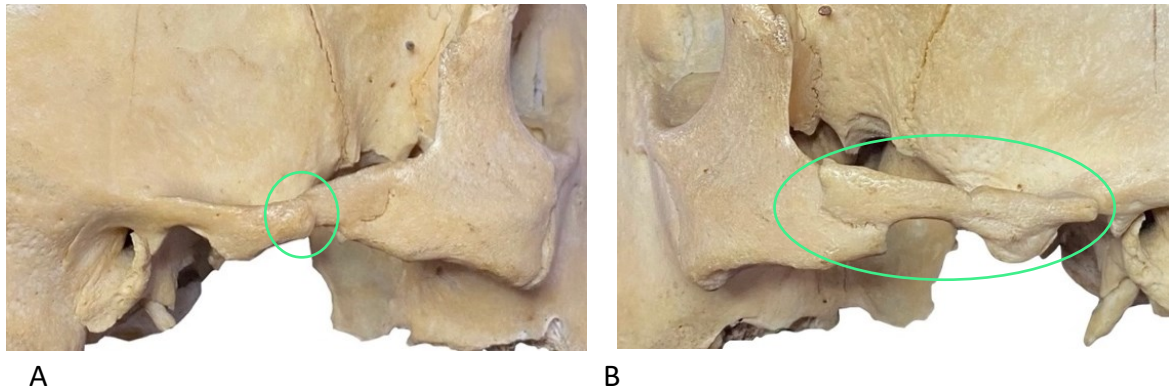


Figure 56. Picture of the right (A) and left (B) zygomatic bone of the Peruvian skull 2871 shows the fractured zygomatic process of the temporal bone.

In addition to the bilateral zygomatic fracture, the individual suffered a skull fracture. This fracture is hidden by the trepanation hole, but can be traced by three fracture lines ending at the suture (Figure 57). Although the fracture lines are already very well healed, the x-ray image clearly shows two fracture lines as well as irregular new bone formation around the internal trephined area (Figure 58 Figure 59).

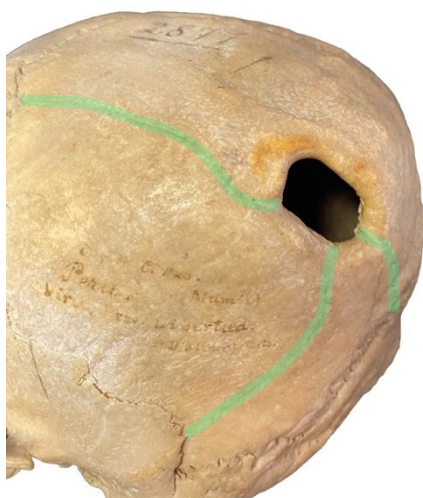


Figure 57. Picture of fissures (highlighted in green) resulted due to a fracture at the left parietal bone of the Peruvian skull 2871.

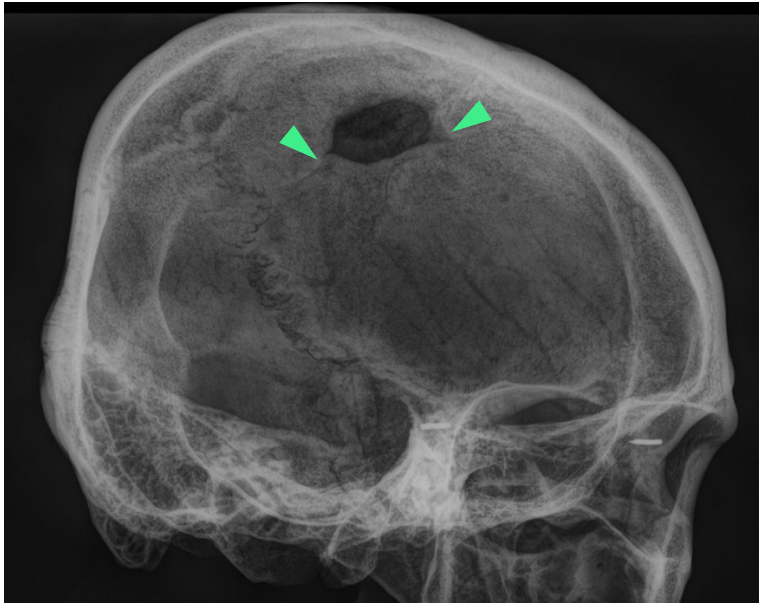


Figure 58. Radiograph of the skull fracture from the Peruvian individual 2871. Green arrows indicate fracture lines.

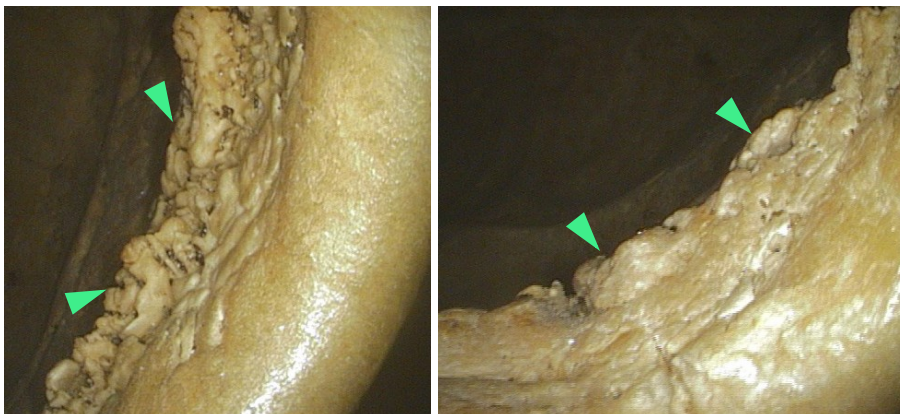


Figure 59. Endocranial part of the trephined cranial area shows new bone formation of the Peruvian skull 2871. Image was taken with an Endoscope XL Go A5020.

The mummified head with inventory number **5877** from Peru shows several traumas. The right zygomatic process of the frontal bone and part of the zygomatic bone along the orbital rim is broken off, shows a uniform darker coloration and signs of healing (Figure 60, red highlighted area).

In addition, there is a big fracture (Figure 60, green highlighted area) with a large irregular hole and sharp edges in the middle of the frontal bone that extends to the bregma. The following characteristics of a so-called green-stick fracture can be found in this mummy:

radiating fracture lines (Figure 61, arrows), irregular fracture margins and splitting (Figure 61 A) and some sharp fracture margins (Figure 61 B).

A small piece of bone has broken off on the right side of the frontal bone (Figure 60, blue highlight). The posterior fracture line is formed by the coronal suture. At the inferior end of the fragment, another fracture on the right superolateral orbital rim. Part of the orbital cavity is erupted here. At this fracture, no color differences can be seen between the fracture margins and the surrounding surface.

Finally, this head shows a completely healed additional depression fracture at the left parietal bone with no inflammatory signs (Figure 62).

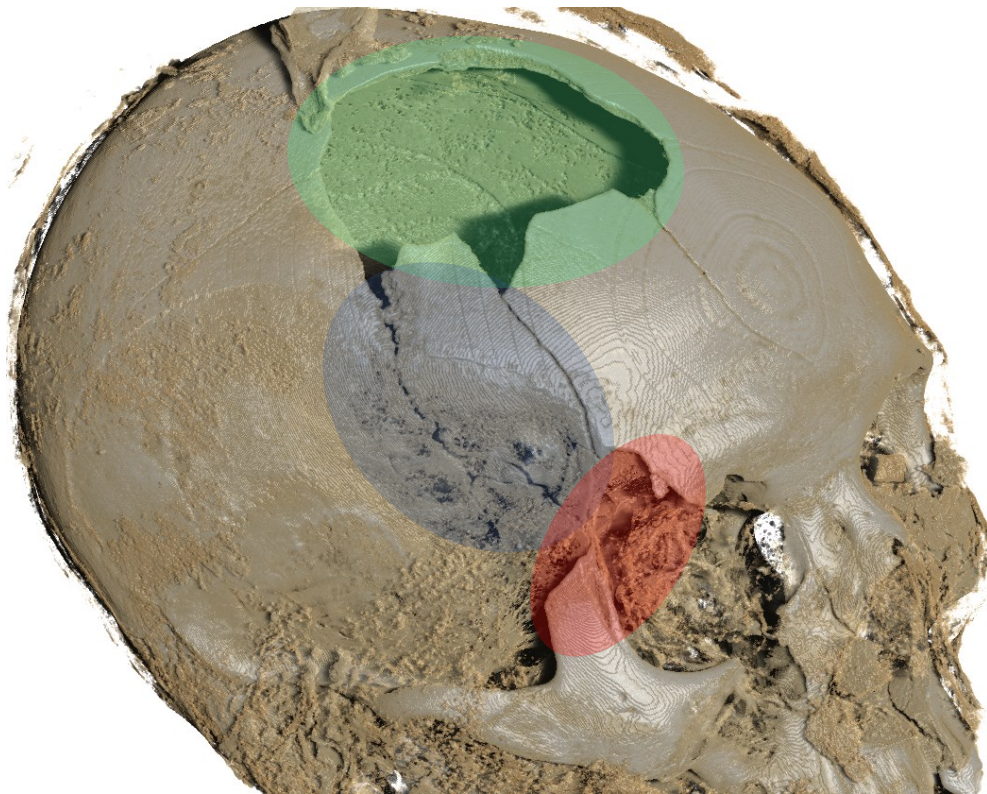


Figure 60. 3D visualization of the μ -CT pictures from the Egyptian mummy 5877. The colored areas show the different fractures. The green highlighted area shows the large missing bone at the cranial vault, the grey area shows the fragment of bone that was repositioned for the μ -CT scan, and finally the red area highlights the fractured parts on the orbital rim.

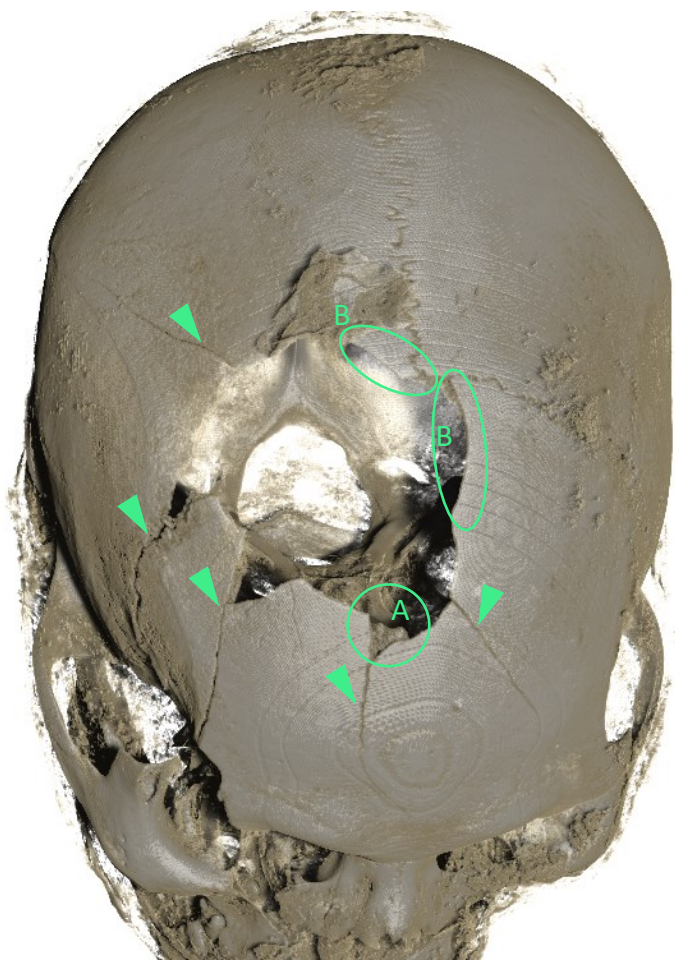


Figure 61. 3D visualization of the μ -CT picture from the Egyptian mummy 5877. Arrows indicates radiating fracture lines, green circles showing: (A) splitting of a bone part and (B) sharp fracture margins

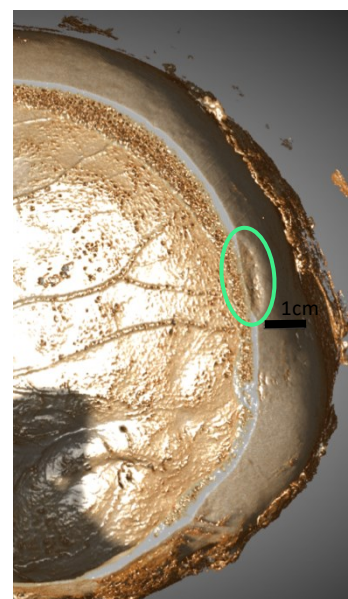
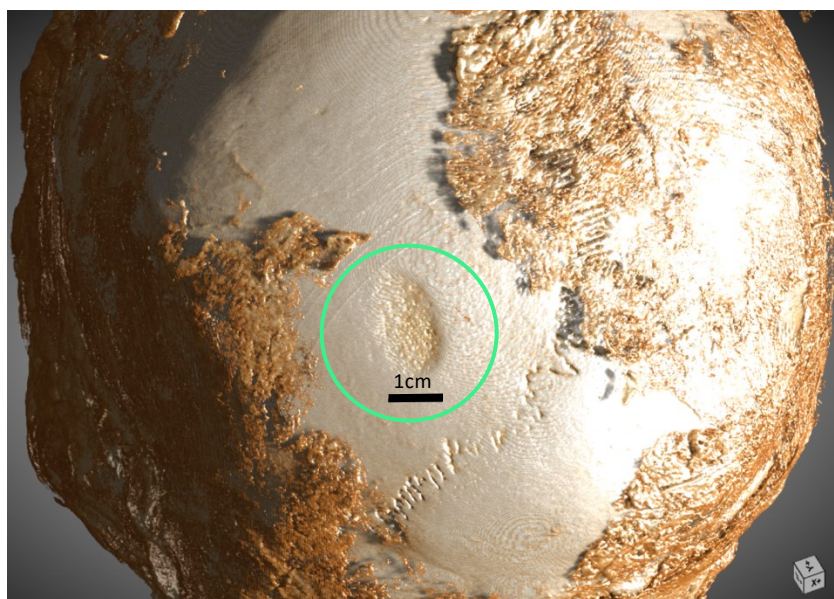


Figure 62. Green circles indicates the depression fracture in the 3D visualization of mummy 5877 from Egypt.

Figure 63 A, B and C shows the skull trauma of the mummified head 15378 from Egypt based on the 3D visualization. To better visualize the visible fractures, the crack trajectories were traced in Figure 63 D, E and F. What is not visible from the 3D visualization, but only when viewing the individual μ -CT slices, are the smaller and finer cracks on the frontal bone (Figure 64).

The frontal bone on the mummy 15378 shows no depression or chipping at the point of force application. A series of radiating linear fractures have formed from this point. These star-shaped fractures extend laterally along the parietal to the temporal bone and along the frontal bone. The fracture lines penetrate the entire bone and are consequently also visible from the inside of the skull. There are no signs of healing visible based on the CT images of the head.

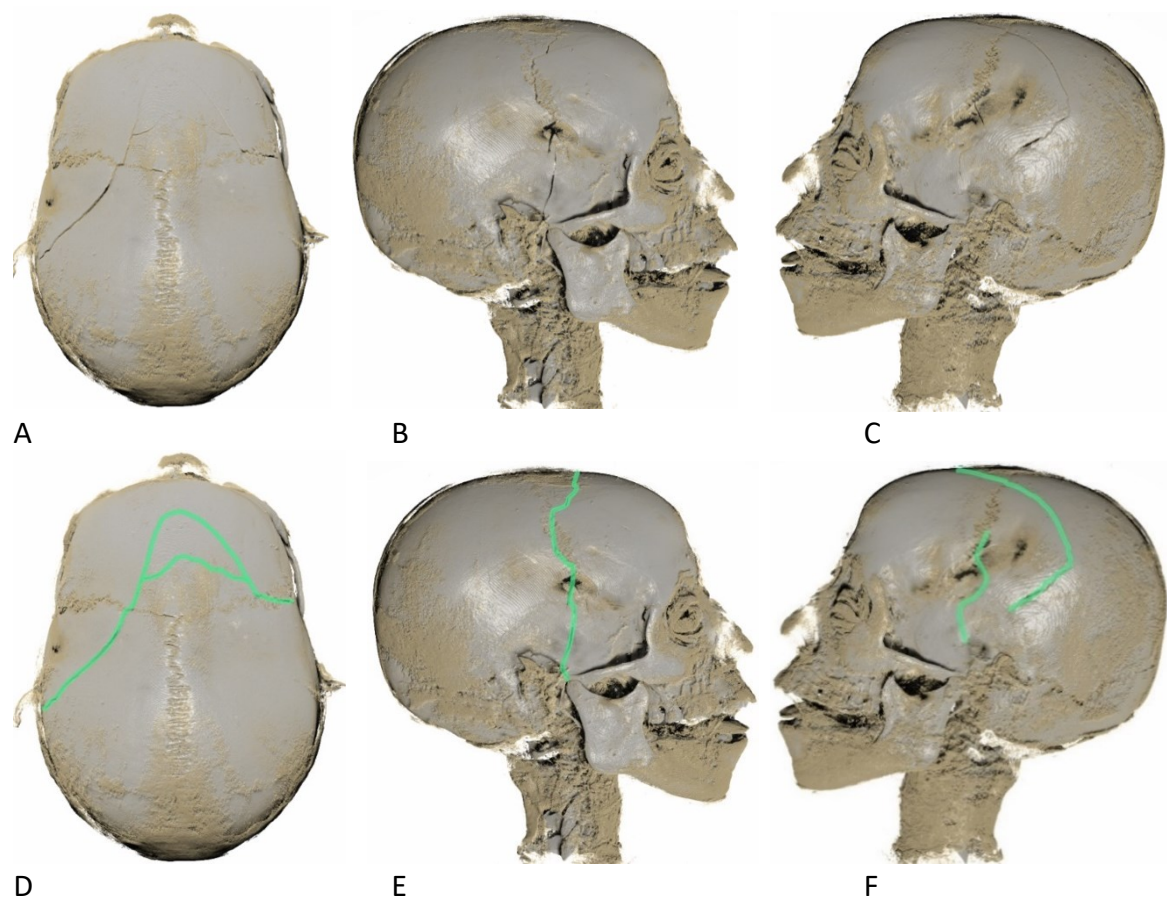


Figure 63. 3D visualization of the Egyptian mummy 15378 shows the trauma from an axial (A), right sagittal (B) and left sagittal (C) view. In picture D, E and F the crack trajectories from A-C are marked in green.

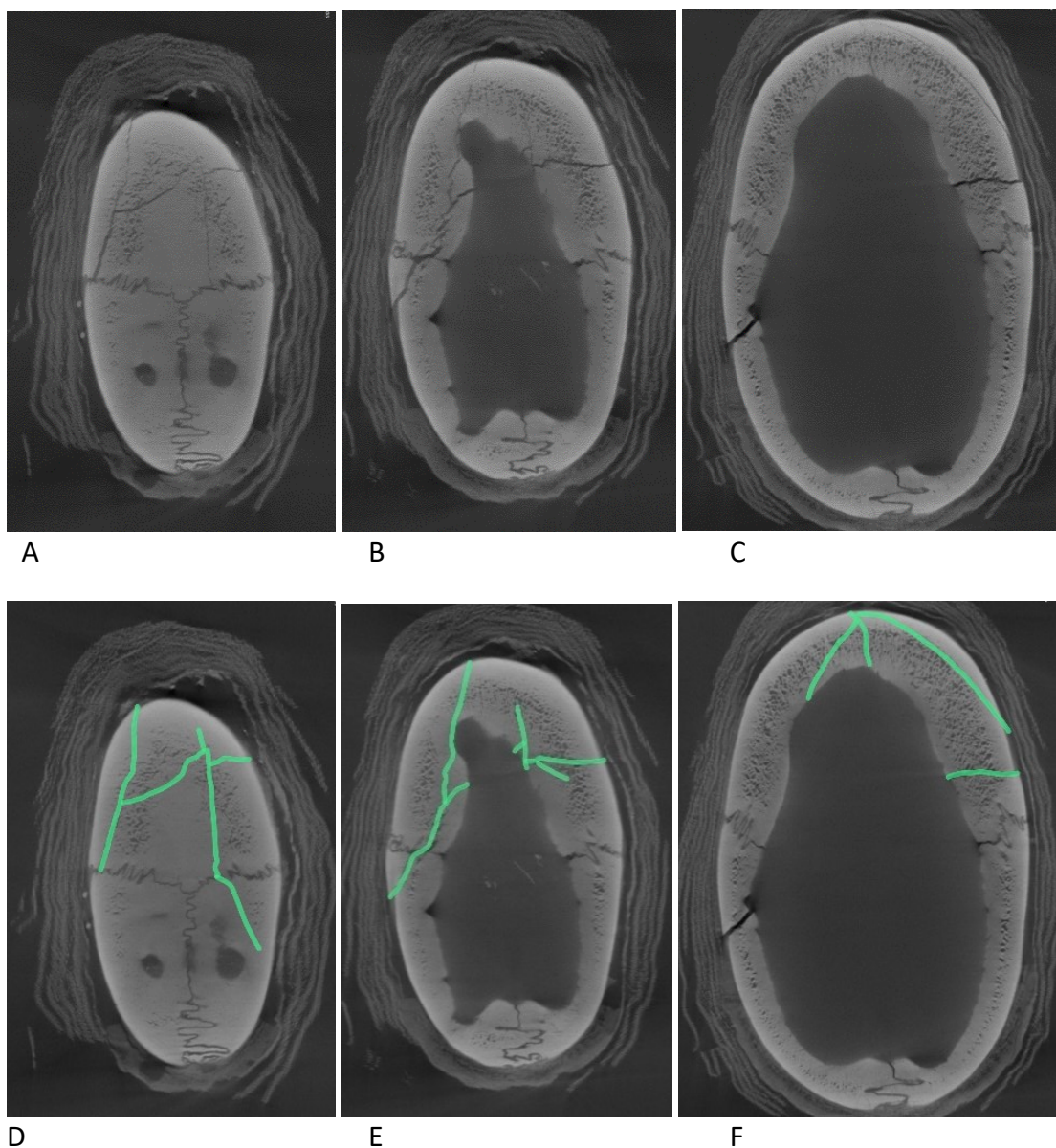


Figure 64. μ -CT slices of the mummy 15378 shows the trauma from an axial slice view (A-C). In pictures D-F the crack trajectories of A-C are marked in green.

3.8 Taphonomy

3.8.1 Bone color

Most of the skulls (15/21) show the classic yellow to brown or ivory bone color. Only a few of the skulls do not show any of the classic bone colors, but other coloration patterns (Table 31).

The Egyptian skull with the inventory number 2231 is completely grey with some darker grey spots at the cranial vault (Figure 65). Skull 5042 from Egypt shows two different colors (Figure 66). In the facial region, the skull is whitish in color, while the rest of the skull is yellow to brown.

In the individuals 1523, 1525, 2877 and 5036 all from Peru, the skull show primarily a yellow to brown coloration, but there are also some bright white areas mainly on the maxilla and the occipital regions (Figure 67).

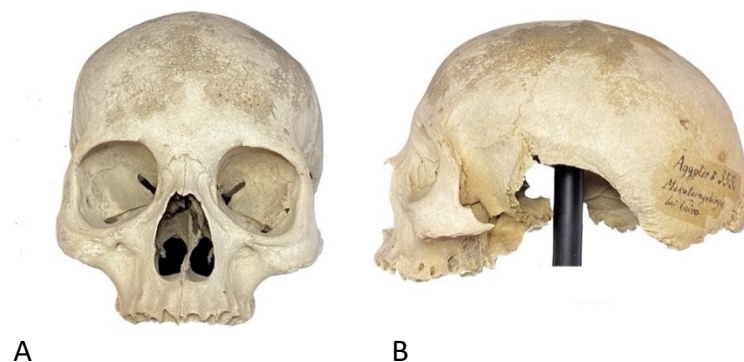


Figure 65. Coronal (A) and left sagittal (B) view of the Peruvian skull 2231 shows greyish coloration.

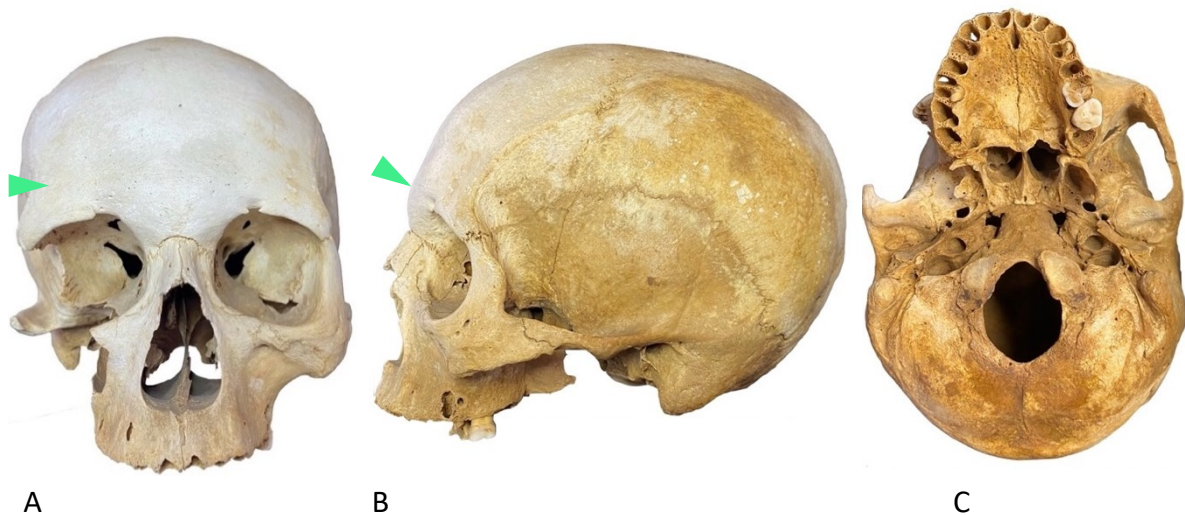


Figure 66. Coronal (A), left sagittal (B) and inferior (C) view of the Egyptian skull 5042 shows different colorations.

The facial region is white (green arrow), while the rest of the skull is yellow to brown.



Figure 67. Coronal (A), left sagittal (B) and inferior (C) view of the Peruvian skull 1525 shows bright white areas (green arrow).

3.8.2 Staining

Staining was examined on bare bones, but also on the wrapped skulls. A total of five skulls shows staining (Table 31), in four of them (2859, 2871, 2875 and 4912) dark reddish brown staining were found respectively around a fracture, at the parietal bone, at the mandibular fossa and at the occipital bone.

There is greenish staining visible at the outer surface of the maxillary alveoli, the palatine process and at the teeth of the skull 5036. (Figure 69). On the occlusal surface, some teeth show greenish staining (Figure 76).

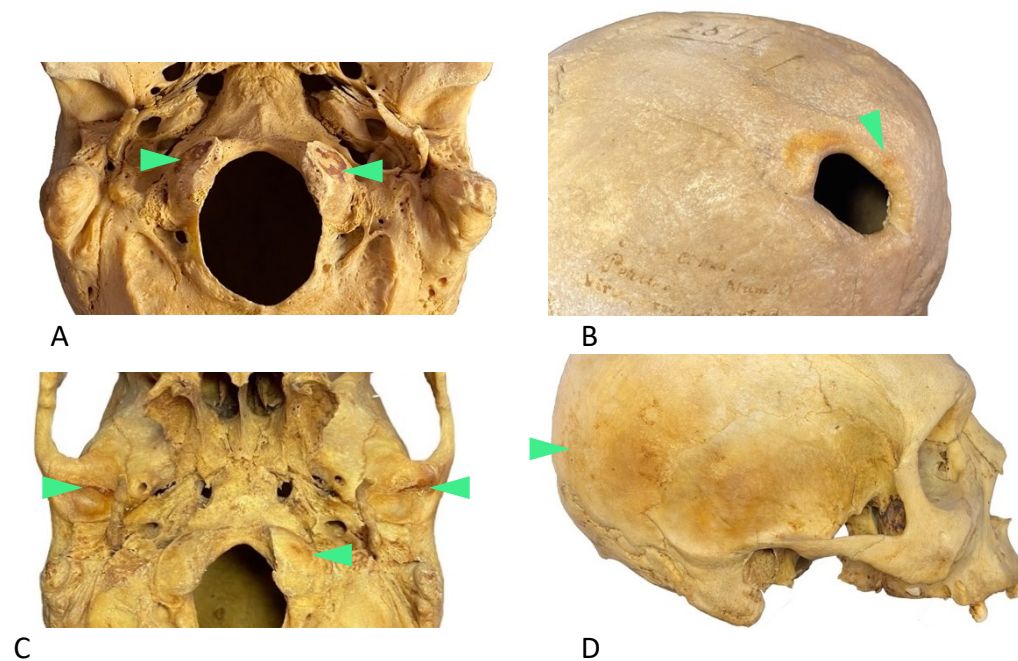


Figure 68. Dark reddish brown staining (green arrow) on the skulls 2859 from Egypt (A), 2871 (B) and 2875 both from Peru (C) and 4912 from Egypt (D).



Figure 69. Inferior picture of the maxilla of the Peruvian skull 5036 shows greenish stained teeth and a slight green staining of the palatine bone.

3.8.3 Bone weathering

Only one of the 24 analyzed individuals (Egyptian mummified head 5043 – Figure 77) shows signs of white with surrounding yellowish-brown bone weathering corresponding to stage 1 on the forehead, parallel to the fiber structure (Table 31).



Figure 70. The green circled area shows stage 1 of bone weathering on the frontal bone of the Egyptian mummified head 5043.

3.8.4 Surface damage

Five of the 24 individuals analyzed show surface damage on the bone, the soft tissue or on the embalming material (Table 31).

On one of these skulls, burn marks are present. Some parts of the skull 2229 are stained black to dark brown on the outer edges of the dental alveoli of the maxilla, the outer edges of the zygomatic bone and of the mastoid process (Figure 71). Just a small amount of the skull is affected. Probably this skull was burned to reduce their volume and/ or to eliminate the bad smell. This possibility is described by D'Anastasio et al. (2021) on human remains from Egypt.

The other four skulls, all Egyptian, show insect damage. At the cranial vault of the mummified head 28 the bandages show small, round holes, up to 5mm in diameter (Figure 72 A). There is a little insect hole located at right pterion of the skull 4912 (Figure 72 B). The mummified head 5877 show some small holes on the bottom of the skull (Figure 72 C) and at the lambda there is an elongated narrow tunnel in the bone. Hundreds of small holes can be seen on the mummified head 14726, especially on the facial area, but also on the side areas and along the throat. At the occipital bone no holes are visible. Large holes are also scattered all over the skull. These holes are very randomly shaped,

have very round and irregular edges, and in some places extend to the bone (Figure 72 D).



Figure 71. Left sagittal view of the skull 2229 shows burn marks at the dental alveoli and the zygomatic bone (green arrows).

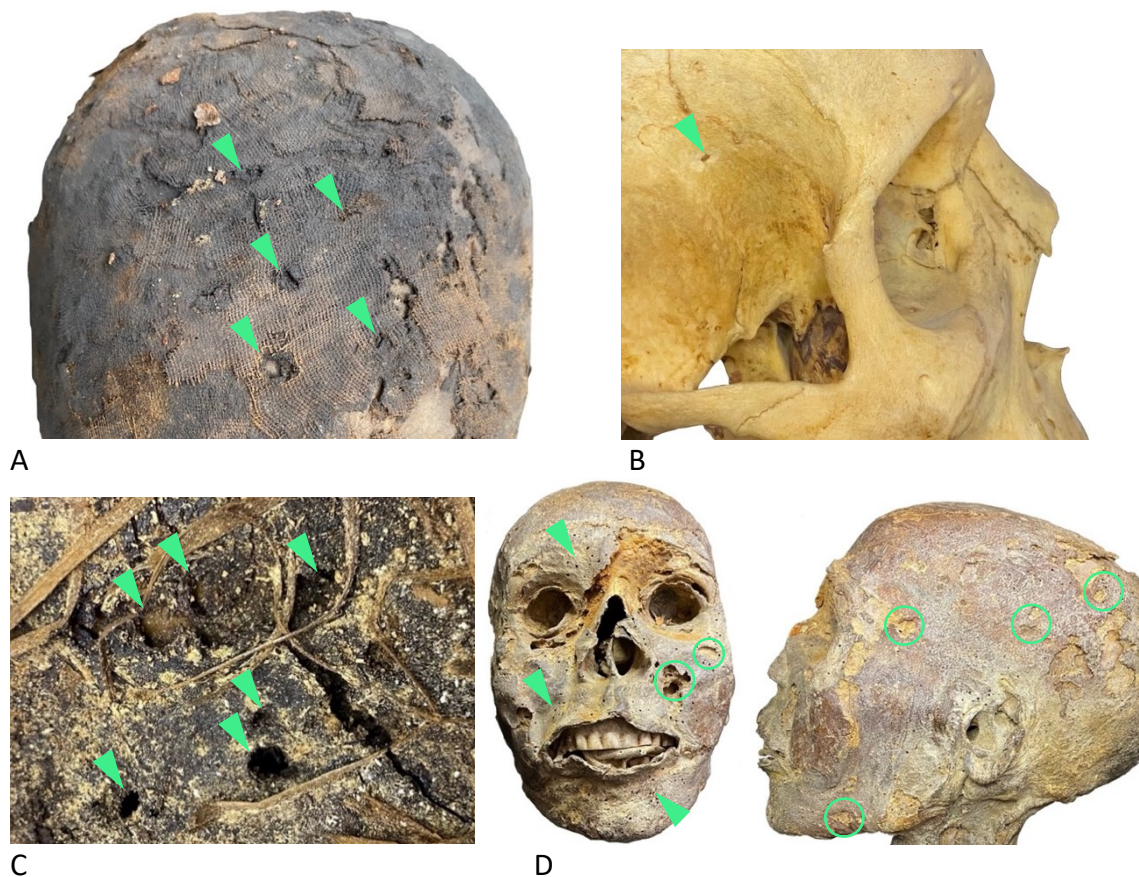


Figure 72. Green arrows indicating the small holes at the mummified head 28 (A), the skull 4912 (B) the mummified head 5877 (C) and the mummified head 14726 (D), all from Egypt. Green circles in Figure D display bigger insect holes.

3.8.5 Adherent material and evidence of mummification on skeletonized skulls

Among the skeletonized skulls, there are only one out of five individuals from Egypt and three out of ten individuals from Peru with embalming or soft tissue remains. In one out of five Egyptian skeletonized skulls and in three out of ten Peruvian skeletonized skulls, at least small remains of a previous embalming or mummification tissue is visible (Table 31).

Individual 1525 shows black embalming material in the nasal conchae as well as at the posterior clinoid process and in the gaps on the basilar part of the occipital bone. There is dark embalming material or desiccated tissue left in the nasal cavity of the skull 2875, (Figure 73 A), as well as organic remains at the styloid processes, the maxilla and the mandible. On the occipital of skull 2877 (Figure 73 B) hardened dark filling material mixed

with grass (embalming material or desiccated tissue) can be observed. The skull 4912 shows small areas of dark brown overlay at the occipital bone (Figure 73 C).

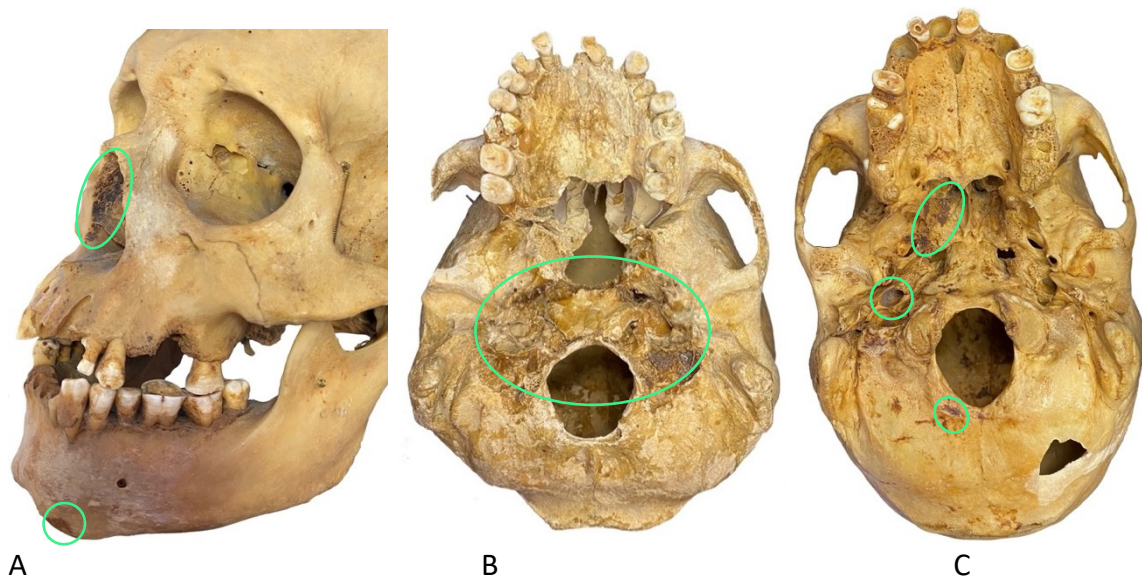


Figure 73. Green circles indicate examples of areas with remains of embalming or soft tissue on the skulls 2875 (A), 2877 (B) and 4912 (C).

3.8.6 Adherent material and evidence of mummification on mummified heads

The facial part of the New Hebrides mummified head **5** is covered with clay, hence the nickname “The clay face”. While the still existing right ear and also the nose were modeled in great detail, not much effort was spent in modeling the eyes. The orbital cavities are filled with clay and then a thumb-thick hole was punched into each eye socket (Figure 74).

A strand-like structure can be seen on the inside of the jaw extending bilaterally from the posterior end of the mandible to the posterior end of the palatine bone of the maxilla. Probably this strand extends through the nose, around the frontside of the mandible back at the inside of the jaw to the palatine bone into the nose again. The strand was covered with clay on the front side of the jaw. Possibly these strands were attached to hold the mandible in position. The strands have a bast-like structure and a width of up to 7mm.

In the cavity formed between the posterior end of the maxilla, the pterygoid process and the inner side of the ramus of the mandible there is a small straw bundle on both sides.

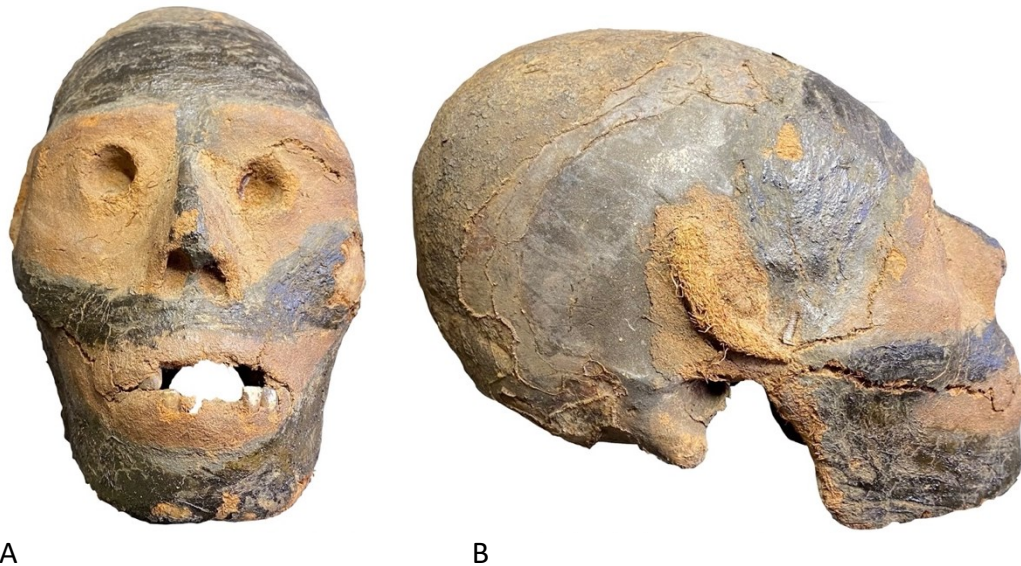


Figure 74. Picture of the New Hebrides mummified head with the number 5 "The Clay Face" 5 shows the modelled face with the remodeled right ear (B), nose and eyes (A).

In contrast, in some areas of the Egyptian mummified head **28**, remains of skin can be seen. On the left parietal bone, there are also very short hairs on top of the skin. Some parts of the skin are still covered by multiple layers of bandages. A bandage piece from the cranial vault shows, that the fabric density is 25 threads per 1cm (Figure 75). On the mandible there are also still some small remnants of skin and bandages.

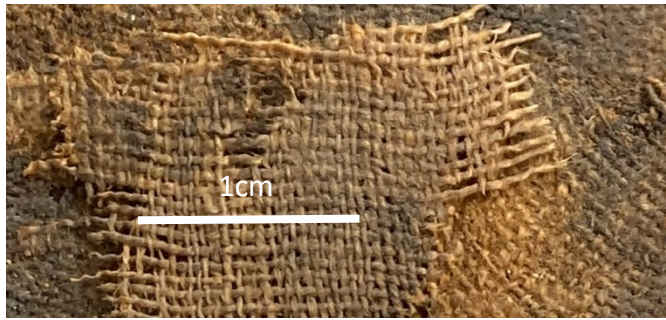


Figure 75. Bandage piece from the cranial region of mummy 28 with a thread density of 25 threads per 1cm.

It seems, that the Egyptian mummified head **2478** is not wrapped with additional embalming material. Skin is for the most parts very well preserved and hairs are visible. On the outside, the mummy was embalmed with a black, shiny resin-like substance. In addition, some areas around the mouth and the right eye contain gold applications (Figure 76). The ears are well preserved on both sides and the nose is also still partly intact.



Figure 76. Black covering of the mummified head 2478 with some gold application at the facial region.

Similarly, the Peruvian mummified head **2876** is still partly covered by skin, but eyes and mouth are plugged with unknown material. The eyes, as well as the lateral parts of the face and the forehead show some remains of soft tissue (skin). Above this tissue on the

left side of the forehead, on the nose and in the mouth a yellowish wool fabric can be observed (Figure 77), possibly camelid fur or skin (personal communication by Bernardo Arriaza- University Tarapaca, Chile - January 30, 2021). Bilaterally the shape of the ears are clearly visible; the palatine bone is surrounded by a dried layer of skin. Dark brown hair with a slightly red tint is quite well preserved. The CT images showed that a not yet identified object with a density comparable to that of bone was packed into the yellowish material stuffed into the mouth.



Figure 77. The Peruvian mummified head 2876 shows remaining hairs and a yellowish tissue on partly covering the dried skin.

The Egyptian mummified head **5043** shows large, uncovered bone areas, fragments of skin on regions where the overlying inorganic material has cracked away and small remnants of bandages. Therefore this head was probably first wrapped with bandages and then plastered with a black material. On the left side of the face, the otherwise black overlay shows a shiny red hue. The shape of both ears is still recognizable as well as lips. Even the anatomical shape of the nose and both nostrils are still well preserved.

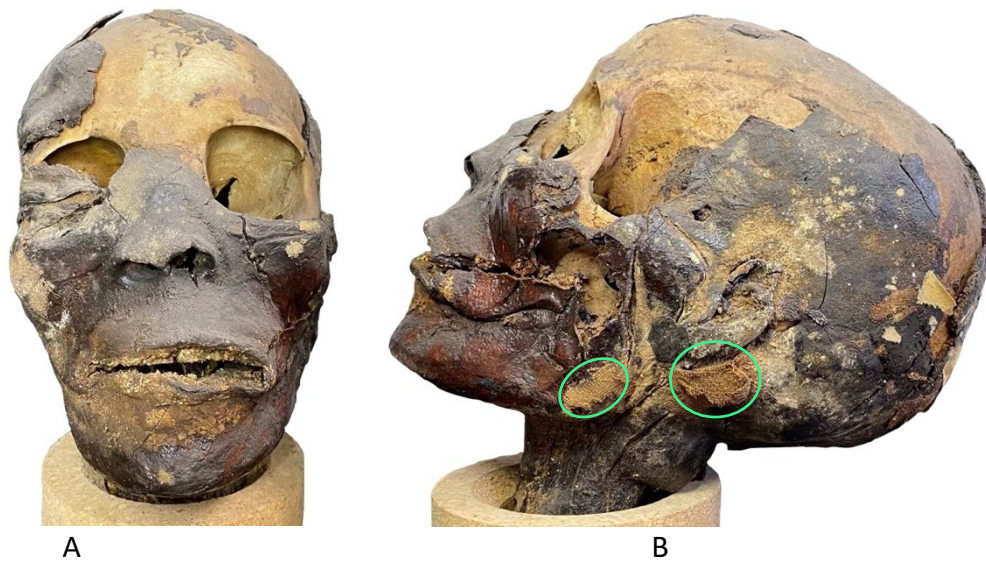


Figure 78. Picture of the Egyptian mummified head 5043 shows the very well preserved mouth part and nose (A), the ear (B) and the skin and some bandage remains (green circles).

Unfortunately, the Egyptian mummified head **5877** is in a bad condition. The left eye and the mouth is stuffed with a scrunched-up textile, that is already missing in the right eye. The shape of the nose is only partially preserved, the tip of the nose is broken off, but the shape of both ears is still partially recognizable. The lower lip is clearly visible, but a large part of the upper lip is missing.

The entire covering material of the skull surface is very irregular and varies in thickness. In some places the skull is covered with several layers of bandages. These are covered with a thin undefined substance that looks like mud. Due to the poor state of preservation, the fiber density of the bandages cannot be determined. Straw appears all over the skull and also between the individual layers, which was apparently also used as embalming material.



Figure 79. Egyptian mummified head 5877 showing poor preservation and some organic and inorganic remains.

A totally different image is transmitted by the Egyptian mummified head **9200**, whose external surface shows no traces of additional embalming material. The ears are very well preserved, but the right ear is rolled up. The shape of the nose is also very well preserved, even though it might have been slightly deformed due to storage conditions. The left eyelid is very well preserved as are both eyebrows and small bunches of about 1cm long hairs all over the skull (Figure 80). The entire skull is covered with a light brown undefined material.



A B
Figure 80. Picture of the Egyptian mummified head 9200 shows the very well preserved skin, eyelids, nose (A) and ear (B).

Still another mode of preservation can be seen in the Egyptian mummified head **14726**, mostly still covered with skin. The left ear is still very well preserved, while the right ear is only recognizable in rudiments. The eye sockets are surrounded by a layer of dried skin. The nose is only partially preserved: while the left nostril is still well recognizable, the right one is largely destroyed. However, lips, tongue and neck are well preserved (Figure 81). Fine hairs of about 0,5 cm in length, are distributed over the entire cranium. Furthermore, the cranium, mouth cavity and cheeks are filled with a bandage material.



Figure 81. Picture of the Egyptian mummified head 14726 shows the very well preserved skin, nose, lips, tongue (A) and left ear (B).

Similarly, ears, nose and even the tongue of the Egyptian mummified head **15378** is also very well preserved (Figure 85). However, in contrast to the former mummy, this one is almost entirely covered with bandages. In the places where bandages are no longer present, like at the occipital bone, the skin is still very well preserved and dark brown to black in color. On the left temporal bone, both the bandages and the underlying skin have fallen off, but a small part of muscle fibers is visible (Figure 82). Two different mesh sizes of bandages were used as preservation material and to keep everything in place. It looks like the skull was first wrapped with a finely woven material with long and wide strips. Then on the facial area a more coarsely woven bandages were cut to size and placed on it. The pictures in Figure 83 and Figure 84 show the two different mesh sizes of the bandages from different parts of the skull. The eyes have not been reshaped. Only where the eyes are located, 1 cm holes were omitted in the bandages.



Figure 82. Picture of the left side of the parietal bone of the mummy 15378 showing the different layers of the bandages (green circle) and the small piece of muscle fiber (green arrow). On the bone the inventory number “15378” is written.

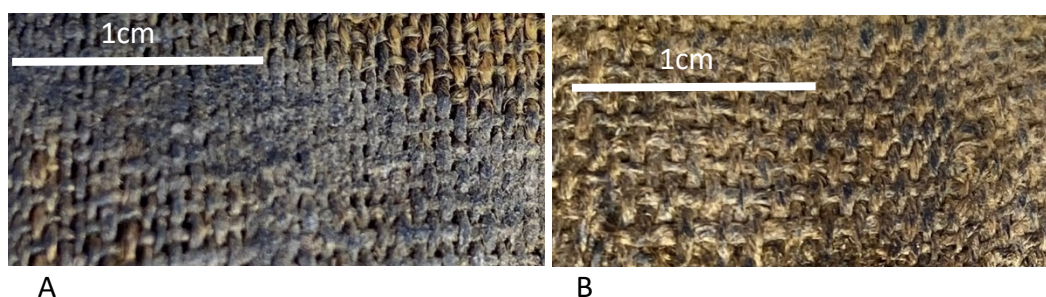


Figure 83. Bandage piece from the facial region (A) and the nose (B) of mummy 15378. Both have a thread density of 18 threads per 1cm.

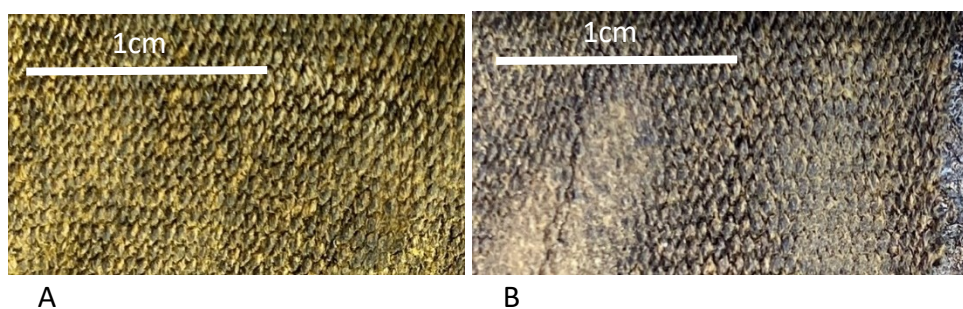


Figure 84. Bandage piece from the neck (A) and the right cheek (B) of mummy 15378. Both have a thread density of 42 threads per 1cm.



Figure 85. Picture of the Egyptian mummified head 15378 shows the very well preserved embalming material, nose, lips and tongue (A) and the left ears (B).

3.8.7 Cultural modification

Only two out of 12 individuals, originating from Egypt show a possible excerebration through the nasal cavity, this includes the inventory numbers **5877** and **15378**. Furthermore, the Peruvian skeletonized skull **2872** shows a possible excerebration through the nasal cavity as well. Additionally, four out of 12 of the Egyptian mummified heads have remains of brain inside the skull. The New Hebridean head show special cultural paintings applied to the clay (Table 31).

3.8.7.1 Excerebration

The nose of the mummified head **5877** is partially destroyed. It is not possible to tell if and to what extent the conchae are present. However, through the opening in the skull, it gets clear, that the cribriform plate is missing. Figure 86 A shows some fine structures in both nostrils, which could also just be stuffing material (green circle) and the missing cribriform plate and crista galli (green arrow). In the 3D visualization in Figure 86 B a part of the

vomer and the perpendicular plate can be seen. According to these findings, excerebration through the nose is possible.

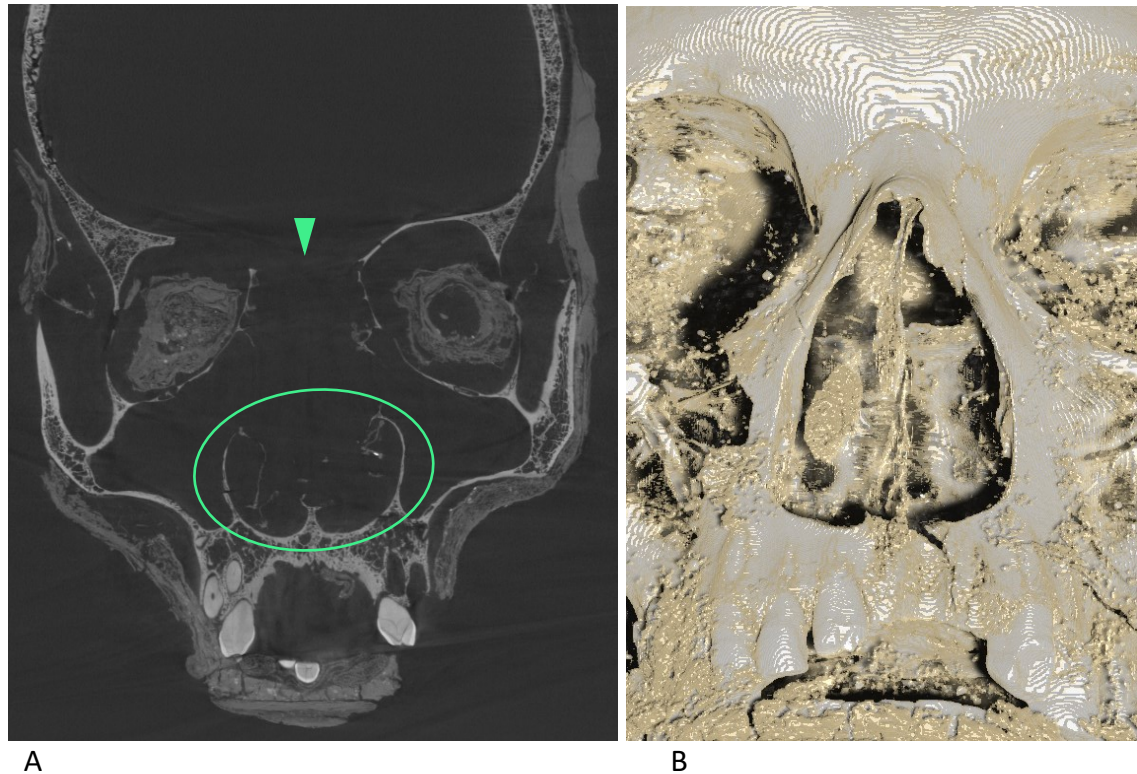


Figure 86. μ -CT slice (A) and 3D visualization (B) from the Egyptian mummy 5877 shows the nasal cavity. A green circle indicates fine structures in the nostrils and the arrow shows where the cribriform plate and the crista galli should be present, but is not.

There are no brain remains or filling material left inside the mummified head **15378**. Excerebration through the foramen magnum can be excluded, since there are still five vertebrae in anatomically correct position and surrounded by soft tissue. Also, an additional opening of the cranium was not performed for this process.

The nose shows signs of damage. Both inferior chonchae are present. However, the right nostril is significantly larger than the left. The perpendicular plate also looks like it was pressed onto the left side (Figure 87 A). Looking from the posterior side at the crista galli and the cribriform plate, it seems that this part is completely missing. It is possible that a part of the cribriform plate fell obliquely into the left nostril while pushing through the right nostril (Figure 87 B). This might indicate a trans-nasal excerebration.

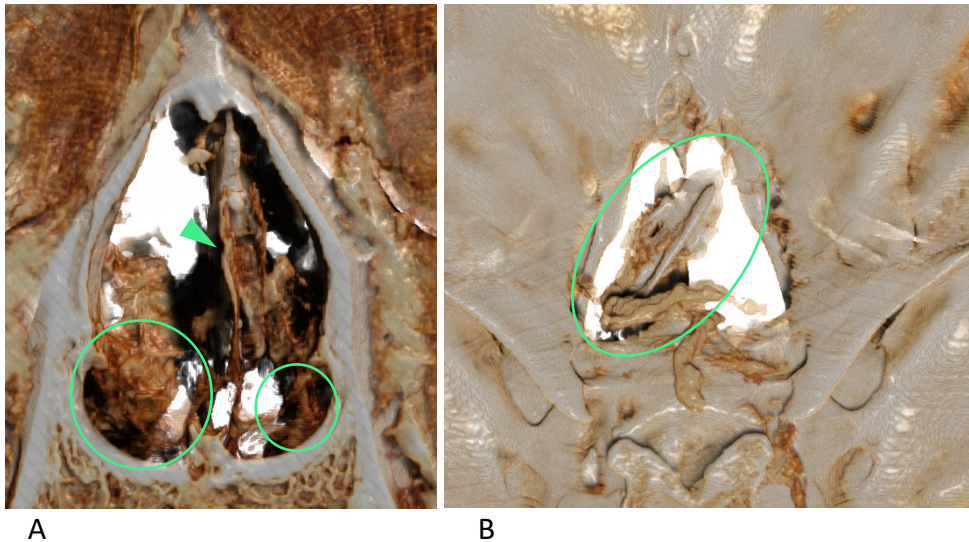


Figure 87. 3D visualization shows nasal cavity from the Egyptian mummy 15378. (A) coronal view of nasal cavity shows inferior nasal conchae (green circle) and crooked perpendicular plate (green arrow). (B) posterior view shows displaced cribriform plate (green circle).

As seen in Figure 88, it can be assumed that the skeletonized skull **2872** had a brain removal through the nasal cavity, since neither the cribriform plate nor the perpendicular plate are present. Also the ethmoid bone and all conchae are missing. According to this, excerebration is possible.



Figure 88. Picture shows the destroyed ethmoid region of the Peruvian skeletonized skull 2872.

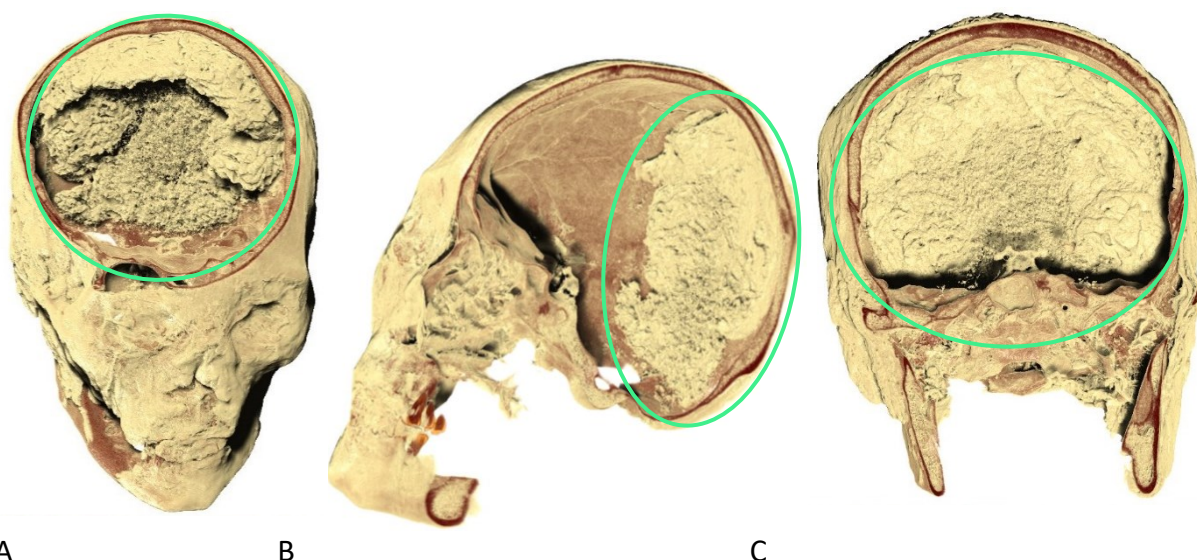
3.8.7.2 Brain remains

At the interior of the mummified head **28** from Egypt there are three loose dried fragments, which are probably desiccated brain (Figure 89). Due to the fact that the face is so badly destroyed, it is impossible to say whether an excerebration through the nose or preservation of the brain by inserting embalming material through the nose was attempted. However, since the left middle and superior concha is present, excerebration or brain preservation through the nose can be excluded.



Figure 89. Picture from inside the skull of the Egyptian mummified head 28 showing the three main parts of the dried brain and some broken fragments.

Apparently, no excerebration through the nasal cavity was performed at the mummified head **2478**, suggesting that no material (tissue material, brain or embalming material) was transported in or out through the nose. This can be concerned based on the fact, that the CT-scans shows, that a lot of material is inside the skull which could be remains of dried brain. Figure 90 shows the round flat substance in the posterior part of the skull.

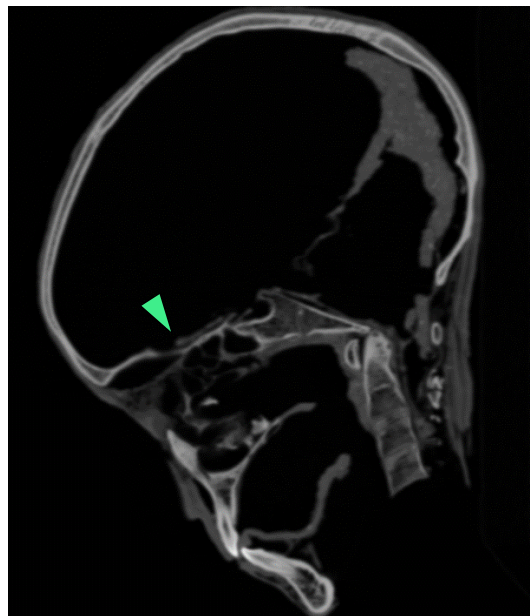


A B C
Figure 90. Axial (A), left sagittal (B) and coronal (C) sectional image of the CT 3D-visualization from the Egyptian mummy with the inventory number 2478.
The green circle indicates the tissue inside the brain.

No excerebration through the nasal cavity was performed on the mummified head **9200**. This has three main reasons. First, the first four cervical vertebrae appear to be completely present (Figure 91), suggesting that no material (tissue material, brain or embalming material) was transported in or out through the foramen magnum. Second, the CT-scans reveal an intact upper ethmoid bone with an also intact cribriform plate, as well as, third, considerable quantities of material left inside the skull which could be remains of the dried brain. Figure 92 shows the round flat substance in the posterior part of the skull and a reticular material extending posteriorly from the middle of the skull. Personal conversations with Bernardo Arriaza (University Tarapaca, Chile – February 10, 2021) confirm this assumption and suggests that the light brown substance coating the material inside the skull could possibly be the dura mater (green arrows in Figure 92).



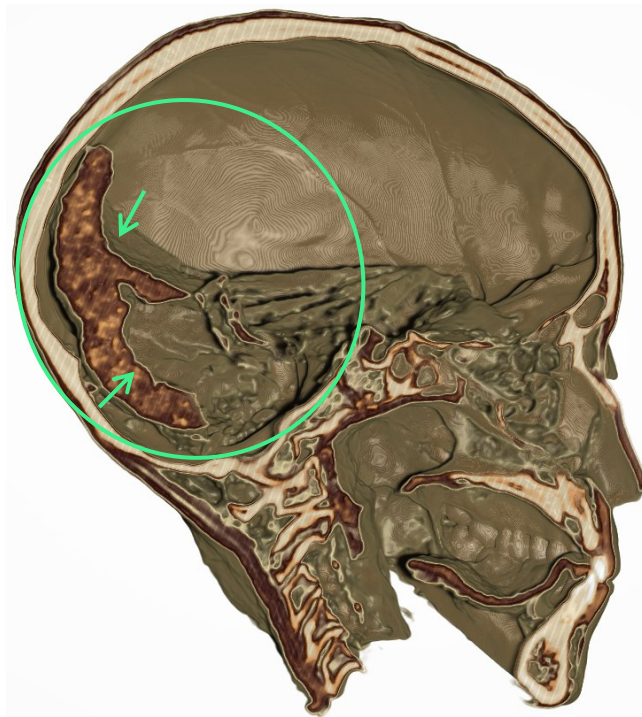
A



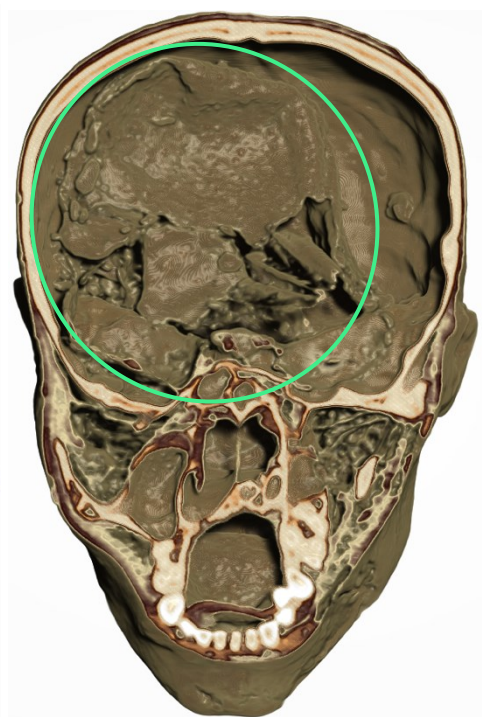
B

Figure 91. Coronal slice of the CT-scan from the Egyptian mummified head 9200.

This picture shows the intact upper ethmoid bone (A). Figure B shows intact cribriform plate (green arrow) and four cervical vertebrae in correct anatomical position.



A

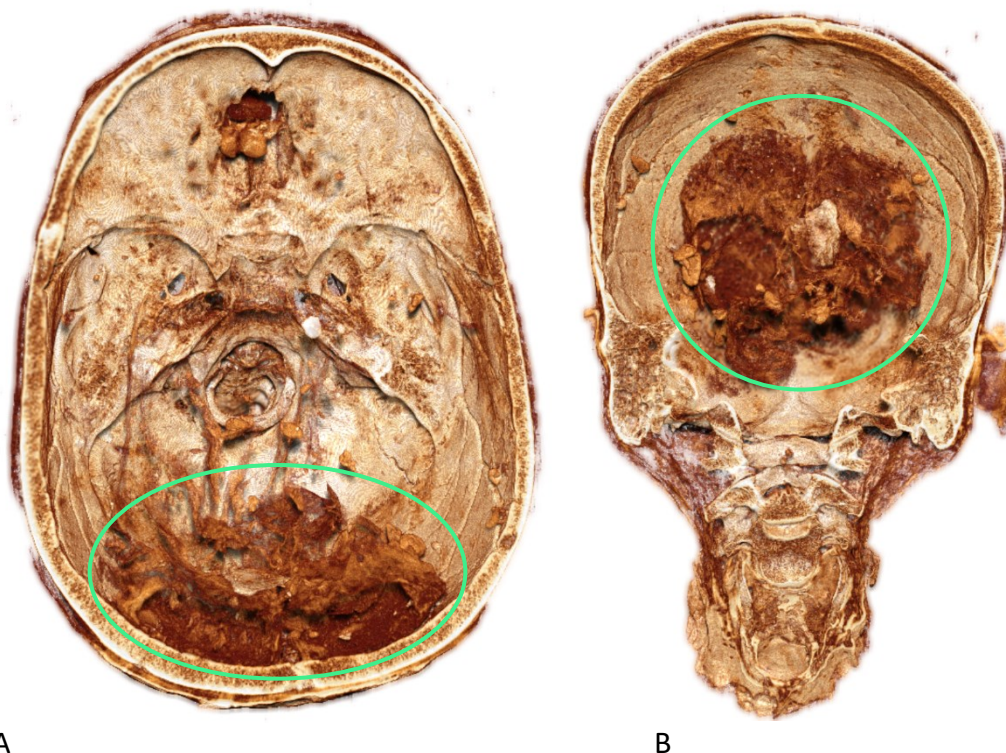


B

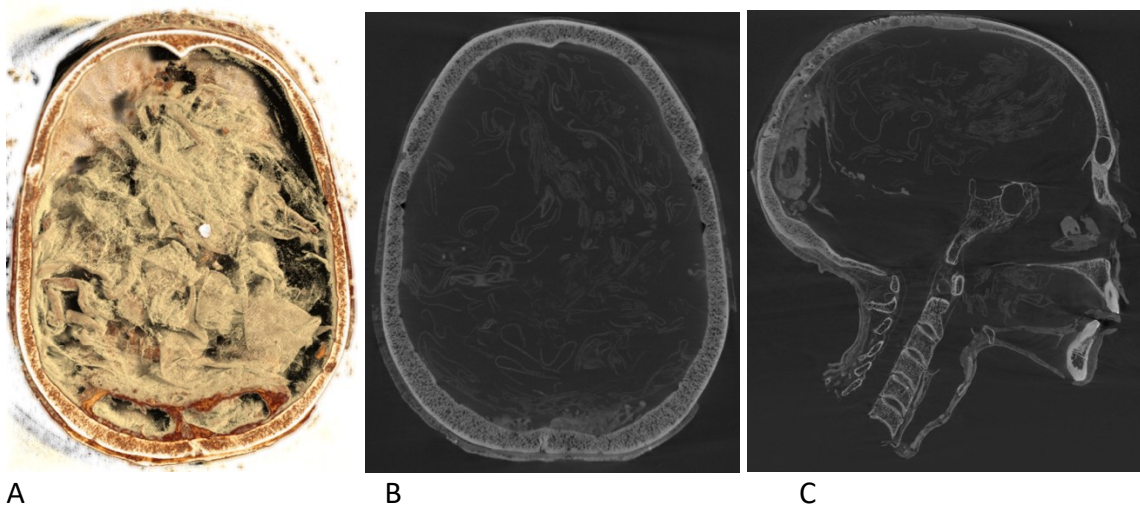
Figure 92. Right sagittal (A) and axial (B) sectional image of the CT 3D-visualization from the Egyptian mummified head 9200.

The green circle indicates the tissue inside the brain.

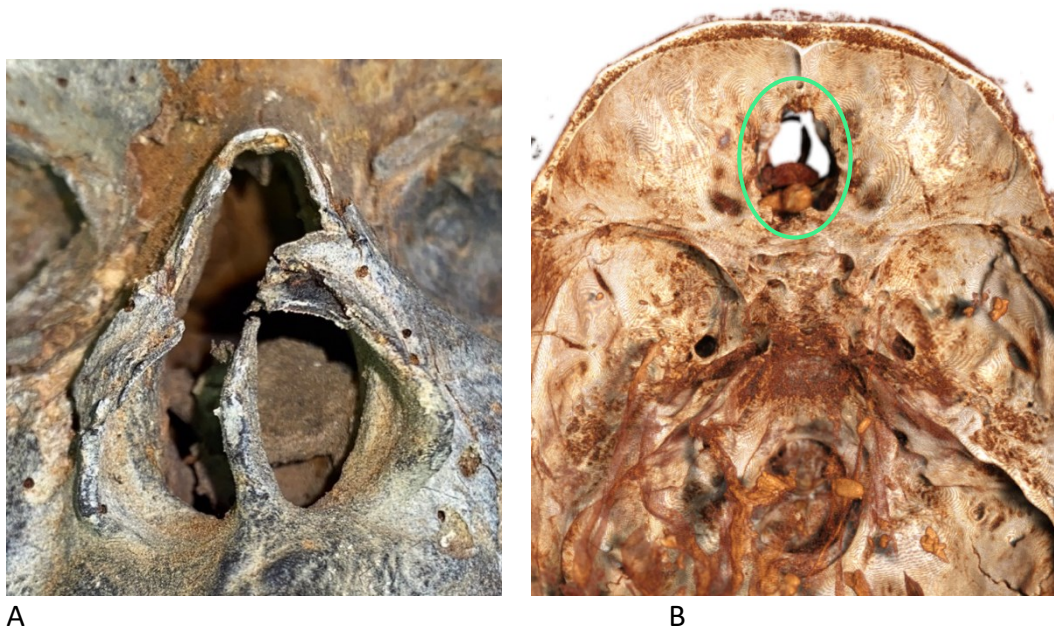
The brain was probably also not removed from the mummified head **14726**. Figure 93 shows, that there is still some soft tissue inside the skull. Since the soft tissue remains are located at the back of the head, it can be concluded that the skull was positioned at the occipital bone for the time of desiccation. Additionally, the cranium was stuffed with filling material to support desiccation (Figure 94). The filling material was most likely transported through the nose into the interior of the skull. Stuffing through the foramen magnum can be excluded, since there are still six vertebrae in the anatomically correct position and surrounded by soft tissue. Also, an additional opening of the cranium was not performed for this process of stuffing. Based on Figure 95, the apertura piriforme can be clearly seen. Whereas the left nostril is still well preserved, the interior view shows that both conchae are no longer present and the vomer and the perpendicular plate are missing. The penetrated and destroyed cribriform plate indicates that something was pushed through the nose.



A B
Figure 93. Axial (A) and coronal (B) interior view of the 3D visualization of the Egyptian mummified head 14726 reveals the soft tissue remains left inside the skull.



A B C
Figure 94. Picture of the stuffing material inside the Egyptian skull from mummified head 14726. (A) coronal view of 3D visualization, (B) coronal view of μ -CT picture, (C) sagittal view of μ -CT picture.



A B
Figure 95. Frontal view (A) of the nasal piriform aperture of the Egyptian mummified head 14726 showing the absence of the conchae, vomer and perpendicular plate. The interior view (B) of the 3D visualization showing the missing cribriform plate and cribriform galli.

3.8.7.3 Cultural mummy paintings

The mummified head 5, whose face is covered with clay, shows a 5cm thick black stripe that extends between the two ears across the forehead, ending with the eyebrows (Figure 96). Between the two eyebrows, a thin stripe about 1cm wide continues to the tip of the nose. Two stripes extend on both sides starting from the earlobe. The upper stripe, about

2cm thick, passes through the zygomatic bone and the maxilla, and the lower stripe, up to 4cm thick, passes across the maxilla. The mouth region was omitted.

In some places the parietal bone is also black, but in a different shade than on the face. It could be possible that the once overlying skin layer was also colored in black. The color may have penetrated and discolored the underlying bone.



Figure 96. Black face painting of the mummified head number 5 "The Clay Face".

3.8.8 Curation modification

Modification on the nine heads and 15 skulls analyzed herein that can be traced back to curational practices can be observed on 22 of them (11 from Egypt and 11 from Peru). Whereas the New Hebridean mummified head number 5 "The Clay Face" and the Egyptian mummified head 5043, both show no form of curation modification directly on the head, all other individuals showed inscriptions either attached to the head, bone, soft tissue or embalming material; small notes were also sometimes written and subsequently attached to the skulls. In all cases, except for the Egyptian mummified head 2478, the inscription was written in black ink, usually on the left parietal bone and the left mandibular ramus and contained the following types of information: inventory number, information about

the place of discovery, the name of the collector and a reference to the year in which the object was inventoried. Mummy 2478 showed only a paper attachment with the inventory number written in lead pencil. Figure 97 shows an example of the inscriptions on the skull and mandible. The mandible attachments made of brass wire are still visible in nine out of ten Peruvian and in two out of five Egyptian skeletonized skulls.

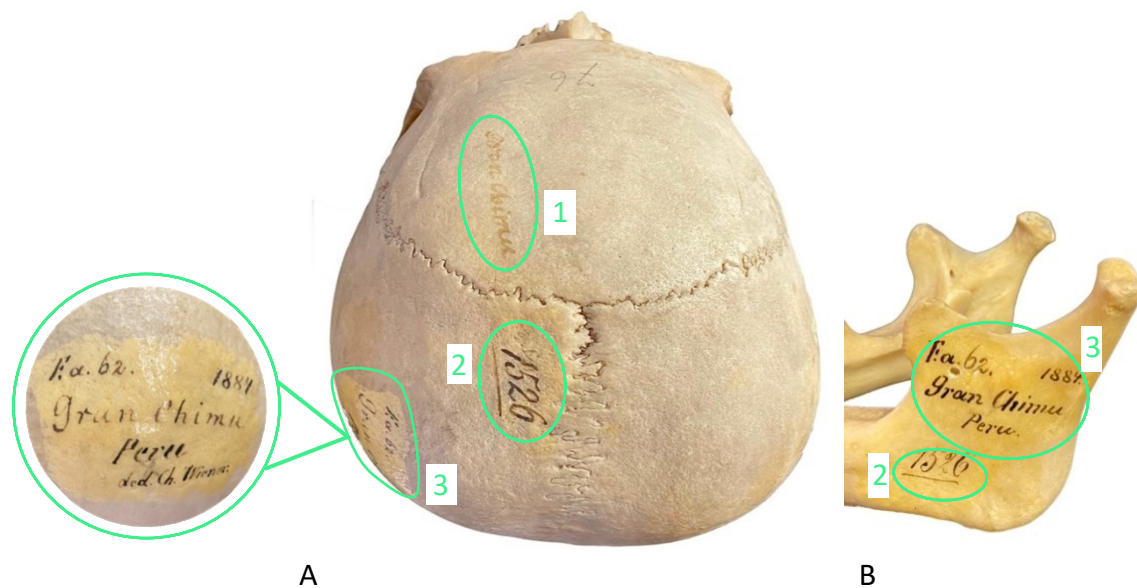


Figure 97. Picture of the inscriptions on the cranial vault (A) and the mandible (B) of the skull 1526: Place of origin (1), inventory number (2), and year in which the object was inventoried, place of origin and collectors name (3).

Finally, an unknown material seems to have been used by curators for the demummification or skeletonization of the skull 2877, explaining its actual bad state of preservation. The entire skull, including the mandible, were covered with a clear varnish, which is now largely flaking off.

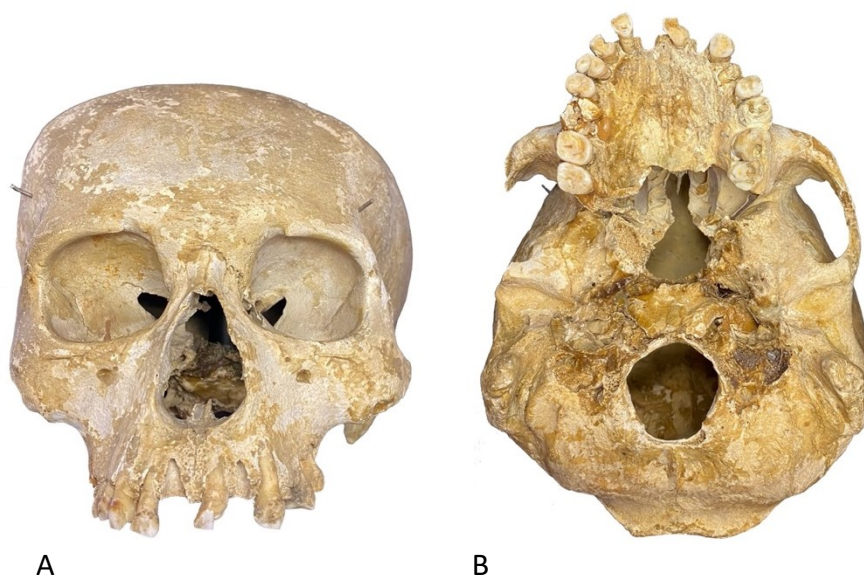


Figure 98. Coronal (A) and inferior (B) picture of the Peruvian skull 2877 shows traces of demummification.

3.8.9 Scientific use

Five of the 12 Egyptian as well as five of the 11 Peruvian individuals show no traces of scientific use. On the remaining 7 Egyptian and 6 Peruvian skulls/ heads either anatomical marking on the bones or laboratory cut marks for samplings can be observed (Table 31).

During the analysis carried out for this thesis C14 dating were obtained for two Egyptian and two Peruvian individuals (Table 30). The marks the tissues sampling caused on these skulls/ heads are included into the above quantification.

A conventional ^{14}C age of 2552 ± 20 years before present was obtained for the sample of the cervical vertebra of the Egyptian mummified head **5043** with the lab number 49874. The calibrated date fits with 95% within 796 – 571 BC. The sample contained 3.4% collagen, which contained 26.6% carbon. But the C:N ratio of 3.8 is slightly beyond the range of 2.9-3.6 considered for well-preserved collagen. Thus, this value possibly indicates degenerated collagen. The corresponding ^{14}C age may be affected by this and could represent an too high or too low estimation (Lindauer, 2021).

The Egyptian mummified head **14726**, with the lab number 49872, shows a conventional ^{14}C age of 2929 ± 25 years before present, that was obtained with a fragment of the internal soft tissue. The calibrated calendrical age fits with 95% within 1217 –1020 BC.

Data on collagen and carbon to nitrogen ratio are missing from this analysis because age was calculated using a tissue rather than a bone fragment (Lindauer, 2021). Furthermore, samples from this individual were taken additionally from the following parts of the skull: internal skin, external skin from the anterior neck and a plant fiber from in-between the external neck skin and cervical vertebrae. However, no results are yet available on these samples.

Some fragments of both styloid processes provided a conventional ^{14}C age of 1106 ± 19 years before present for the Peruvian skull **2875** with the lab number 49873. The calibrated calendrical age fits with 95% within 893 – 992 AD. The sample contained 8.0% collagen, which contained 44.0% carbon. The C:N ratio of 3.3 is within the range of 2.9-3.6 considered for well-preserved collagen. According to this, the age calculation is considered to be reliable (Lindauer, 2021).

A fragment of a cervical vertebra provided a conventional ^{14}C age of 566 ± 20 years before present for the Peruvian mummified head **2876** with the lab number 49871. The calibrated calendrical age fits with 95% within 1322 – 1419 AD. The sample contained 12.2% collagen, which contained 45.8% carbon. The C:N ratio of 3.5 is within the range of 2.9-3.6 considered for well-preserved collagen. According to this, this age calculation is considered to be reliable (Lindauer, 2021). Furthermore, samples were taken from the following parts of the skull: external skin, internal nasal bone, hair for zoological analysis, hair for chemical analysis and cotton from the mouth cavity. However, no results are yet available on these samples.

Both Egyptian skulls are much older than the Peruvian skulls, with a calibrated age long before Anno Domini. An interesting fact about the two Peruvian individuals is that they differ in age, even though both skulls come from the same site, Viru, and are listed with consecutive inventory numbers.

Table 30. Result of the analyses of the ^{14}C dating from the Curt-Engelhorn-Zentrum Archäometrie gGmbH in Mannheim (Lindauer, 2021).

Origin	Inv. Nr.	Lab Nr MAMS	^{14}C Age [yr BP]	$\pm$	Probability 68% [yr]	Probability 95% [yr]	C:N	C [%]	Collagen [%]	Material
Egyptian	5043	49874	2552	20	cal BC 791-673	cal BC 796-571	3.8	26.6	3.4	bone
Egyptian	14726	49872	2929	25	cal BC 1199-1056	cal BC 1217-1020		59.6		soft tissue
Peruvian	2875	49873	1106	19	cal AD 897-989	cal AD 893-992	3.3	44.0	8.0	bone
Peruvian	2876	49871	566	20	cal AD 1327-1407	cal AD 1322-1419	3.5	45.8	12.2	bone

Table 31. Summary of the taphonomic characteristics. Inventory numbers of the mummified heads are highlighted in green. Not highlighted inventory numbers correspond to skulls (that used to be mummified but where skeletonized).

Origin	Inv. No.	Bone color	Staining	Bone weathering	Surface damage	Adherent material	Cultural modifications	Curation modification	Scientific use
Egyptian	28	Yellow to brown	No	No	Insect damage on bandages	Skin and hair remains; multiple layers of bandages	Remains of dessicated brain; no excerebration	Paper attachment; inscriptions on the bone	Anatomical markings
	2229	Yellow to brown	No	No	Burn marks	No	No	Mandible attachment; inscriptions on the bone	Laboratory cuts
	2231	Grey	No	No	No	No	No	Inscriptions on the bone	No
	2478	N.o.	N.o.	No	No	Skin and hair remains; embalmed with black shiny resin-like substance, gold applications	Remains of dessicated brain; no excerebration	Paper attachment	No
	2859	Yellow to brown	Dark reddish brown	No	No	No	No	Mandible attachment; inscriptions on the bone	No
	4912	Yellow to brown	Dark reddish brown	No	Little insect damage	Dark brown embalming or tissue remains on occipital bone	No	Inscriptions on the bone	Anatomical marks, laboratory cut marks
	5042	White and brown	No	No	No	No	No	Inscriptions on the bone	No
	5043	Yellow to brown	No	Stage 1	No	Skin and bandage remains, plastered w. black material	No	No	¹⁴ C dating – 2552 ± 20 yr BP
	5877	N.o.	No	N.o.	Insect damage	Several layers of bandages, mud, straw	Probably excerebration through nose	Inscription on the bone	No
	9200	Yellow to brown	No	N.o.	No	Skin and hair remains; no additional embalming material	Remains of dessicated brain; no excerebration	Inscription on the skin	Several samplings – no results yet
	14726	Yellow to brown	No	N.o.	Insect damage	Skull almost completely covered with skin; remains of orange, fine, friable material remains	Remains of dessicated brain; stuffing through nose	Inscriptions on the bone	¹⁴ C dating – 2929 ± 25 yr BP
	15378	Yellow to brown	No	N.o.	No	Skin and soft tissue well preserved; partly wrapped with bandages	Probably excerebration through nose	Inscription on the bone	Several samplings – no results yet

Peruvian	1523	Yellow to brown, some parts yellow to white	No	No	No	No	No	Bone parts held together with glue; inscriptions on the bone	No
	1525	Neurocranium yellow to brown, maxilla yellow to white	No	No	No	Black organic/ desiccated tissue in nose, posterior clinoid process and at occipital bone	No	Mandible attachment; inscriptions on the bone	aDNA sampling – no results available
	1526	Ivory	No	No	No	No	No	Mandible attachment; inscriptions on the bone	Anatomical markings
	2871	Ivory	Dark reddish brown	No	No	No	No	Mandible attachment; inscriptions on the bone	Anatomical markings
	2872	Ivory	No	No	No	No	Probably excerebration through nose	Mandible attachment; inscriptions on the bone	Anatomical markings
	2874	Yellow to brown	No	No	No	No	No	Mandible attachment; inscriptions on the bone	No
	2875	Yellow to brown	Dark reddish brown	No	No	Organic/ desiccated tissue remains at nose, styloid process, mandible and maxilla	No	Mandible attachment; inscriptions on the bone	¹⁴ C dating – 1106 ± 19 yr BP
	2876	Yellow to brown	No	No	No	Skin and hair remains; yellowish wool fabric at facial part	No	Paper attachment	¹⁴ C dating – 566 ± 20 yr BP
	2877	Yellow to bright white	No	No	No	Organic/ desiccated tissue remains around occipital bone	No	Demummification traces; mandible attachment; inscriptions on the bone	No
	5036	Yellow to bright white	Green	No	No	No	No	Mandible attachment; inscriptions on the bone	No
New Hebr.	5037	Yellow to brown	No	No	No	No	No	Mandible attachment; inscriptions on the bone	No
	5	N.O.	No	N.O.	No	Facial part covered with clay; skin remains on the posterior part of skull	Black painting on clay; no excerebration	No	Several samplings – no results yet

4 Discussion

A total of 24 mummified heads and skeletonized skulls from individuals whose human remains were taken from different institutions/locations (mostly from ancient Egyptian cemeteries or museums), by 13 collectors in the 19th to 20th centuries and transported to the Natural History Museum of Vienna (NHMW) were examined herein. In fact, they represent 24 case studies. As such and because the individuals to whom these remains belonged cover ages at death from six to 50+, represent both sexes, are testimonials from 10 different (archeological) sites and possibly lived sometime between 796 BC and 1419 AD (according to the dating results), any statistical analysis is meaningless. However, after discovering their countries of origin, and subdividing the case studies in 11 Peruvians, 12 Egyptians and one individual from the New Hebrides, the description of age at death, sex, aspects of health and diseases as well as taphonomic/mummification processes and marks of scientific “use” of each of them as an arbitrary group, allow to better contextualize each group as well as each case individually. Comparing them then to the literature in the following sub-chapters not only adds scientific value to each individual case of those almost totally forgotten mummies of the NHMW, but to mummy studies in general.

4.1 Sex and Age of the heads/skulls according to provenance

While almost the same number of Egyptian and Peruvian skulls were available for examination (12 from Egypt and 11 from Peru), there is only one skull from New Hebrides. As expected, the age at death distribution is unbalanced and varies from six to 50+ years for Egypt, 12 to 50+ years for Peru and is between 20 and 34 years for the New Hebrides skull. The same is true for the distribution of sex, where there is only one male individual available for the New Hebridean case study, more males than females in Peruvian case studies (nine males versus one female) and approximately the same distribution in the Egyptian case studies (five male versus six females).

4.2 Dental health

4.2.1 Dental health in the mummified heads and skeletonized skulls of ancient Egypt

An investigation by Forshaw (2009) describes the oral and dental health in ancient Egypt. This study reveals that ancient Egyptians suffered from extremely abraded teeth, periodontal problems and severe dental abscesses. These findings are roughly compatible with the results of the examinations of the Egyptian mummies of the Natural History Museum presented herein, since the majority show medium to severe dental abrasion, even though they are assumed not to have died very old. Dental abrasion can be an explanation for abscesses, which have been found herein in at least two out of four cases that show highly abraded teeth. In that sense, the Egyptian mummified heads of the NHMW seem not to diverge from these general descriptions.

Forshaw (2009) mentions that the high degree of abrasion is due to the chewing of coarse fibrous diet and the presence of inorganic particles, such as sand, quartz, spar, mica or something similar. As food processing techniques improved, the degree of tooth abrasion decreased in Egypt. Caries were relatively rare (up to 10%) until 400 BC. Before that, a sedentary agricultural lifestyle had been established, resulting in a high-protein and high-carbohydrate diet. But these carbohydrate sources were primarily non-fermentable, preventing dental caries. With the beginning of the fourth century BC, however, there was a change in diet, resulting in an increased consumption of white bread, honey and dates. This increased variety and quantity of fermentable carbohydrates and led to an increase of caries. In the Egyptian cases studied herein half show carious teeth. Two individuals were assigned to a living before 400 BC, on the basis of the C14 determination and both show no carious lesions. Consequently, this corresponds to the findings by Forshaw (2009). For one remaining case with no caries, no C14 date could be retrieved; this however does not mean that the individual to whom these human remains belonged lived before 400 BC.

4.2.2 Dental health in the mummified heads and skeletonized skulls from ancient Peru

The study of Lanfranco & Eggers (2010) describes the dental health status between four different time periods in ancient Peru, ranging from the Formative Period (2500 – 1 BC, Puémape site) to the Late Intermediate Period (1000 – 1470 AD, Los Pinos, Chancay Complex). The Formative Period consists of three different stages: the Early Formative (4400 ± 110 BP) fisher-gatherers, and later the Middle Formative (3920 ± 110 BP) and Late Formative-Salinar (2340 ± 90 BP) who show marine subsistence and an intermediate degree of agricultural development. In contrast to this is the Late Intermediate Period with irrigation agricultural society. The study mentions that the Late Intermediate Period shows a significantly higher frequency of carious lesions than the Late Formative-Salinar Period. This can be attributed to a more cariogenic diet during the Late Intermediate Period (Lanfranco & Eggers, 2010).

Unfortunately, only two Peruvians analyzed herein have a chronological classification to a period. Individual 2876, from the Late Intermediate Period, has a very high caries frequency, which is consistent with the results of the study. Individual 2875, which is a little older and can still be assigned to the Middle Horizon Period (600-1000 AD), again has a very low number of carious teeth.

Furthermore the study states, the amount of ante mortem tooth loss increases from the Early Formative (12,61%) to the Salinar (26,86%) Period again to the Late Intermediate Period (11,53%) (Lanfranco & Eggers, 2010). This result also fits to the two skulls described in the previous section. The mummified head 2876 (Late Intermediate Period) does not show a single ante mortem lost tooth and the skull 2876 (Middle Horizon Period) shows an ante mortem lost tooth rate of only 9.4%. In three skulls the ante mortem tooth rate is even higher than in the Late Formative-Salinar Period: 53% in individual 1526, 34% in individual 2872 and 28% in individual 2874. Accordingly, these results are not consistent with any of the described periods from the study.

In summary, the study by Lanfranco & Eggers (2010) shows that it is not sufficient to conclude on nutritional behavior and subsequently on a possible assignment to a time period by simple frequencies of carious lesions and ante mortem tooth loss. Caries depth,

caries decalcification, tooth wear, oral ecology and archaeological evidence should also be taken into account-as is necessary in all bioarchaeological work. Such a precise analysis was not an aim of this work and thus was not carried out on the skulls/heads of the NHMW.

4.2.3 Dental health in New Hebrides

According to Allibone et al. (2012), in some areas in Vanuatu there is an enormous fluoride contamination of rainwater by volcanic plume. The most affected areas are Tanna, Ambrym and Malakula. Dental fluorosis can have some positive effects on health, but also negative ones. One disadvantage of excessive fluoride intake is that teeth can become more brittle, leading to more frequent antemortem tooth loss. An advantage, however, is that teeth exposed to certain fluoride concentrations tend to develop fewer dental caries. Since neither caries nor abscesses were observed and only one tooth was lost antemortem in the wrapped skull from New Hebrides (Number 5 “The clay face”) from the NHMW, these findings seem to be in accordance with these expectations.

4.3 Intentional cranial modification and Trepanation

4.3.1 Intentional cranial modification in Peru

A very recent study by Gómez-Mejía et al. (2022) revealed the frequency of intentional cranial modification during the Paracas Period (800 – 200 BC) in pre-Columbian Peru. In general, intentional cranial modification was frequently carried out in the Andean region, with geographical and temporal variations. The first evidence for intentional cranial modification dates back to 4000 BC, while the much more recent Inca elites most likely did not modify their skulls anymore.

Gómez-Mejía et al. (2022) concluded that 98% of the people from the Paracas Peninsula in the Paracas period had intentional cranial modification. The most common form was the "tabular erect" form with 59.7%, followed by the "bilobate" form with 23.9%. A picture of the appearance of these two different forms are shown in Figure 99. Compared to this, the frequency of intentional cranial modification in other pre-Columbian Andean Periods is not as high as in the Paracas culture. Accordingly, the frequency of intentional cranial modification varies between 62% during the Early Intermediate Period (200 BC – 600 AD) and 76% during the Late Intermediate Period (1000 – 1476 AD).

Comparing these findings with those of the skulls from the Natural History Museum, similar results are obtained. Almost all Peruvians (10 out of 11) show intentional cranial modification. All of them can be classified as having a tabular form, with some of them showing symmetric bilobed bulging on the parietal bone. Figure 102 and Figure 103 shows all the Peruvian skulls with intentional cranial modification. Left sagittal and superior pictures were chosen to make a comparison to the two most common deformation types from the Paracas Period in Figure 99. Figure 100 shows the only NHMW Peruvian skull, with the inventory number 2875, without intentional cranial modification. This skull is possibly one of those infrequent skulls that simply do not show any modifications. Another possibility is, that this skull was only deformed in a very small extent, making the detection of a deformation very difficult.



Figure 99. Two of the most common types of intentional cranial modification in the Paracas Period: (A) Tabular erect form and (B) Bilobate form. Photos made by Juliana GómezMejía (Gómez-Mejía et al., 2022).

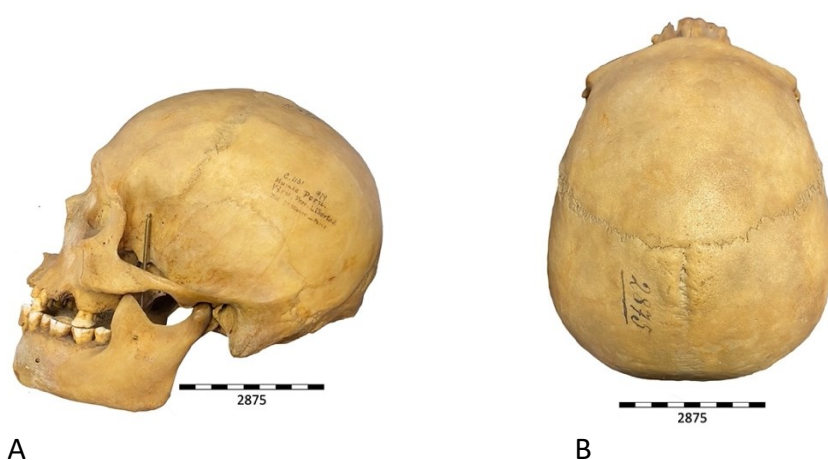


Figure 100. Left sagittal (A) and superior (B) picture of the Peruvian skull that shows no characteristics of intentional cranial modification.

4.3.2 Intentional cranial modification in Egypt

There is intentional cranial modification present in ancient Egypt. Tubbs et al. (2006) describes the deformation of the skull among the Egyptians as aesthetic reasons, preferring an elongated skull and pointed chin. Ayer et al. (2010) states that there is knowledge of intentional cranial deformation in Egypt around the time of the reign of Akhenaten (1375 – 1358 BC) in the 18th Dynasty. Unfortunately, in many cases these findings result from illustrations. Many of the corresponding mummies have never been found and therefore the illustrated skull deformation could not be verified. There are two assumptions about how the cranial deformations were achieved in Egypt. One suggests that the skulls were deformed due to acromegalic or macrocephalic disease, another suggests intentional physical deformation, for example, with the help of bindings during the growth period. One of these causes may also have led to the skull deformation of the skull with inventory

number 9200. Another cause of skull deformation that is unintentionally induced may be caused by postural deformity during the growth period, and that usually is asymmetrical (Captier et al., 2011). This possibility should also be considered as a cause for the skull deformation of skull 9200. Lastly, deformations of the skull can also occur due to taphonomic factors, usually leading to asymmetric shapes.

Skull 2229, in the contrary, shows a very inconspicuous skull deformation with only a slight impression on the frontal bone. Considering that this deformation pattern extends like a strap over the frontal bone, this depression may have been caused due to the wear of headdresses or some kind of headbands, like it was very common during the Second Intermediate Period (Miniaci, 2007). Alternatively this depression might also have been caused by carrying heavy loads with the help of straps around the forehead.

4.3.3 Intentional cranial modification in New Hebrides

Intentional cranial modification in the New Hebrides is a characteristic feature that could also be confirmed in the skull from the Natural History Museum with the inventory number 5. Usually, skulls from this region show circular constriction and no lateral bulging on the parietal bone (Flower, 1882). The greatest degree of modification in the New Hebrides can be seen in the frontal bone, near the bregma. At this region the skull number 5 indeed shows a clear depression. The long cylindrical and characteristic shape of the skull is due to circular constriction on all sides. Determination of the expression of the frontal eminences is not possible with this type of deformation, because they are strongly blurred by the depression of the frontal bone (Flower, 1882; Rüdinger, 1888). A comparison of the mummified head 5 with another New Hebridean skull, published by Rüdinger (1888) and a third one shown in the exhibit "Fernão de Magalhães - Pelos Mares do Mundo Inteiro" at the Museu de História Natural e da Ciência da U.Porto (MHNC-UP) is shown in Figure 101.

White (2015) mentions that the reason for this type of skull deformation in the New Hebrides is the spiritual beliefs of the people in this region. According to this, those people who have an elongated skull are considered more handsome or beautiful and this type of skull deformation is seen as an indicator of wisdom.

Since intentional cranial modification could be observed herein in 13 from the 24 examined cases, taking all regions together, it must be assumed that at least in those cases where the modification is very conspicuous, collectors might have chosen those cases exactly because of this trait. In any case it is known that “items” for osteological collections were chosen also because and due to their degree of exotism. And intentional cranial modification represents such an exotism, although it was practiced in some European regions until some centuries ago (Eccles, 2015; Spindler et al., 1996).



Figure 101. Comparison of left sagittal μ -CT reconstructed picture of the mummy skull 5 “The clay face” (A) with an illustration of Rüdinger (1888) (B) and another comparison can be made between the right sagittal picture of the mummy skull 5 “The clay face” (C) and the pictures of a skull from Papua New Guinea exhibited at the Museu de História Natural e da Ciência da Universidade da Porto (Picture made by Prof. Dr. Sabine Eggers) (D). At all pictures the typical New Hebrides circumferential deformation can be seen very well.



Figure 102. Left sagittal and superior picture of the Peruvian skulls showing intentional cranial modification. Inventory numbers are given below the scalebar. Pictures made by Liesa Geppner.



Figure 103. Left sagittal and superior picture of the Peruvian skulls showing intentional cranial modification. Inventory numbers are given below the scalebar. Pictures made by Liesa Geppner.

4.3.4 Trepanation in ancient Peru

Trepanation by scraping, grooving or cutting was practiced in various parts around the world in prehistoric times. However, the majority of skulls with trepanations were found in ancient Peru (Kushner et al., 2018).

Kushner et al. (2018) investigated the survival rate of individuals with trepanned skulls from the coastal regions and Andean Highlands of Peru, dating back to 400 BC through the Inca Period. There were regional differences in these results, but in general the long-term survival rate for the early periods (400 – 200 BC) is around 40%, while for more recent human remains (1000 – 1400 AD) the long-term survival rate rises up to 91%. Around the time of the Inca Period (1400 – 1500 AD), the average long-term survival rate is between 75-83%. The term "long term" has been used to describe a trephination opening that has completely healed, making the surgery considered successful. Whereas for short-term, the survival time is probably less than two weeks and there is still osteoblastic activity around the trepanation opening. Furthermore, this study concluded that scraping and grooming were the two most used methods for trepanning the skulls. The size of the trepanned holes in Peru varied from openings of 1 cm in diameter to huge openings that could reach dimensions of 9 x 5,7 cm. Most trepanations, although not all, were associated to traumatic cranial injuries. Especially the Inca had the highest trepanation rate which could be associated with trauma (Kushner et al., 2018).

The Peruvian trepanned skull from the Natural History Museum, with the inventory number 2871, can be very well compared with the results from the study by Kushner et al. (2018). That is because skull 2871 involved grooving as a skull opening method, also shows clear long term signs of healing and was also possibly carried out due to treat a fracture.

4.4 Palaeopathology

4.4.1 Diseases and trauma in ancient Egypt

The study by Nerlich et al. (2002) examines different palaeopathologies on ancient Egyptian mummies and skeletons and assigns them to respective ancient time periods. According to this study, porosities in the orbital roof (cribra orbitalia) or the cranial vault (porotic hyperostosis) is reported to be very common among ancient Egyptians. The cause of this porosity can be manifold. Iron deficiency or anemia is named as the main cause. But malaria, which was endemic in ancient history, is also believed to be a cause of porosity in the cranial vault (Smith-Guzmán, 2015), as well as other diseases and taphonomic factors (Rivera & Mirazón Lahr, 2017). These porous lesions occur in the Middle Kingdom, as well as in later periods with a frequency of 30%. During the Third Intermediate Period, however, cribra orbitalia can be observed in 2/3 of all archaeological findings (66%) (Nerlich et al., 2002).

Arthritic changes in the bones tend to vary depending on the time period and the social status and are due to excessive mechanical stress. These arthritic joint changes occur in the Middle Kingdom in 6,2%, in the New Kingdom in only 1,9%, during the Third Intermediate Period in 5% and in later periods even up to 18,5% (Nerlich et al., 2002). Forshaw (2009) mentions that osteoarthritis at the temporomandibular joint is a common feature on Egyptian skulls. This is often caused by an altered mechanical function of the joint, caused by heavy mastication and associated with an increased degree of abrasion of the teeth.

Nerlich et al. (2002) also describes the frequencies of traumatic fractures of the skull among the Egyptians. According to this, fractures of the skull are very common. Hole defects, which, for example, can occur as a result of projectile injuries from stone bullets or arrowheads, are very frequent. In the Middle Kingdom, skull fractures are visible in 21,8% of the archaeological findings. In later periods, the frequency of skull fractures ranges from 12,3% to 22,6%.

Compared to the results of the Egyptian skulls from the Natural History Museum, the expression of cribra orbitalia and porotic hyperostosis were found to occur in similar frequencies (22% cribra orbitalia and 10% porotic hyperostosis) than mentioned in the literature (Zweifel et al., 2009). However, the presence of osteoarthritic changes, with 55%, is far above the average frequencies listed in the literature. The results for skull fractures in the

Egyptian skulls from the NHMW are also in accordance with the literature, since three of 12 skulls show fractures.

4.4.2 Diseases and trauma in ancient Peru

In a study by Dageförde et al. (2014), a meta-analysis was performed to analyze different palaeopathologies of the pre-Columbian South American mummies from a time period between 7050 BC and 1500 AD.

This study revealed that 5% of all examined cases suffered from a bone disease, which included porotic hyperostosis and exostosis of the external auditory channel. Especially in the case of exostosis, the study mentioned that this is a very common trait in the pre-Columbian South American coastal regions, which is caused due to constant, mostly occupational activity, in cold water and or in windy regions (Okumura et al., 2007). The permanent occurrence of ear infections leads to ossification in the area of the external auditory canal (Dageförde et al., 2014). According to Rhys Evans & Cameron (2017), most cases of auditory exostosis are asymptomatic, but they can cause inflammation of the ear canal and present conductive hearing loss with severe ear canal occlusion.

Furthermore, the investigations showed that 4% of the Peruvian individuals analyzed herein suffered from osteoarthritis or osteoporosis. However, these results refer to the sacroiliac joint and the spine and therefore cannot be compared with the osteoarthritic diseases on the skulls of the Natural History Museum. In addition, 14% of the mummies examined in the study showed traumatic injuries on the head.

A comparison of the Peruvian skulls/ heads from the Natural History Museum with the results from the literature shows that some of the outcomes are very different. The Peruvian skulls/ heads of the NHMW show an extremely high occurrence rate of bone diseases. Cribra orbitalia occurs in 55% of the cases and porotic hyperostosis even in 73%. However, while the Egyptians did not have a single skull with exostoses, the Peruvians had two skulls affected. This finding is very compatible with the literary data.

Among the Peruvian skulls in the Natural History Museum, there was only one skull that had a cranial trauma. In this case, however, the individual even suffered from several fractures, all of which were survived at least to some degree.

4.4.3 Comparison of incidences of diseases between Egypt and Peru

Considering the studies by Nerlich et al. (2002) and Dageförde et al. (2014), inter-culturally comparisons can be made, if cautious. Based on the literature, the Egyptians have a higher incidence of cribra orbitalia and porotic hyperostosis than the Peruvians. This result could not be found in the analysis of the mummy skulls from the Natural History Museum. The opposite is the case in these skulls. While the Egyptians show rather low values for cribra orbitalia and porotic hyperostosis, extremely high cases of these diseases have appeared among the Peruvians. A similar diverse result is obtained when looking at the frequency of osteoarthritic diseases of the bones. While in the literature it is stated that in both regions the expression occurs in about 5%, in the skulls from the Natural History Museum this pathology is found in up to 2/3 of all examined skulls. One reason for these diverse results in both cases could be the low number of cases in both the Peruvians and the Egyptians, and of course the fact that none of the subgroups studied herein represent a (part of a) population.

However, the occurrence of trauma curiously matches the literature. According to the literature, the fracture rate is higher among the Egyptians and can reach up to 22.6%, while only 14% of the Peruvians suffered from trauma. Similarly, in the case of the mummy skulls from the Natural History Museum, more fractures were discovered in the Egyptians (25%) than in the Peruvians (9%). This however only means that among the cases studied herein there could be assumed a higher warfare among these Egyptians than among these Peruvians, which cannot be generalized by any means to a certain period of time or a certain archaeological site.

4.4.4 Diseases and Trauma in New Hebrides

Unfortunately, to the best of knowledge, there is no literature on palaeopathologies of ancient skeletal remains from the island region in Melanesia, which also includes the New Hebrides

archipelago. However, a comparison of the results of this study with those from the literature would not be expressive either, as there is only one individual (arbitrary inventory number 5) from this region as a comparative reference.

In summary, most of the cranial features discussed above are roughly in accordance with the literature on Peruvian, Egyptian and New Hebrides ancient human remains. This, in a very indirect manner supports the provenance research carried out herein.

4.5 Taphonomy and mummification techniques

The chapter on taphonomy and mummification techniques will focus on the nine still mummified heads of the Natural History Museum in Vienna. Based on the appearance, the type of mummification and the ^{14}C dating, some conclusions can be made about the origin and the historical age.

Due to the fact that almost no soft tissue is present in the 15 already skeletonized skulls and thus no meaningful comparisons and correlations can be made about their origin and historical mummification techniques, these skulls will not be further discussed herein.

4.5.1 Egyptian mummified heads

More than half of the 12 Egyptian skulls are mummified. The technique of mummification of these seven cases can therefore be satisfactorily compared and discussed within the literature on the corresponding Egyptian region and chronological horizon. In the following paragraphs each mummy head is discussed separately (with the corresponding inventory number in bold letters, for more clarity).

A striking feature of three of the Egyptian mummified heads of the NHMW is the insect damage to the soft tissue and bandage material. This was also described earlier by Abdel-Maksoud et al. (2011). More specifically, the NHMW Egyptian mummy heads show insect damage both within the wrappings and on the bone material. The surfaces of the soft tissue could have been attacked by insects such as moth larvae, Coleoptera insects and red-legged ham beetles, among others (Abdel-Maksoud et al., 2011), that possibly have attacked these human remains while there were still in Egypt Esterhuysen et al. (2009) for example, describes insect feeding on an African mummy, which also shows small holes in the dried skin, possibly caused by blowfly larvae or other insects that burrow holes in the skin. Insects similar to those described above may also have caused the damage of the soft tissue to the Egyptian mummies from the Natural History Museum.

The skeletonized skull 4912 shows a small hole at the right pterion that also may have been caused by insect damage. One insect species that could be responsible for this would be the dermestid beetles. They bore into solid material as well as bones (Wrobel & Biggs, 2018). According to Wrobel & Biggs (2018), these insects also like to eat soft tissue. It is possible that this skull was infested by dermestid beetles near the time of mummification.

The damaged mummified head with the inventory number **28** shows skin and hair remains, as well as multiple layers of bandages. These bandages show a fabric density of 25 threads per one centimeter. According to Letellier-Willemin (2020) similar linen fabrics were found in El-Deir in the Kharga Oasis during the Ptolemaic Period (332 – 30 BC) until the end of the third century AD. During this time the most common fabric density is about 22 to 28 per centimeter. It is possible that the mummified head 28 originates from this, or a later time period, since the places of origin of this – Thebes - and the wrapping material described by Letellier-Willemin (2002) – El- Deir - are only located about 200 km (linear distance) apart. Figure 104 shows some resemblances between the linen sample of the El-Deir region and a bandage sample of the mummified head 28 from Thebes. However, this has to be investigated in more detail in further research.

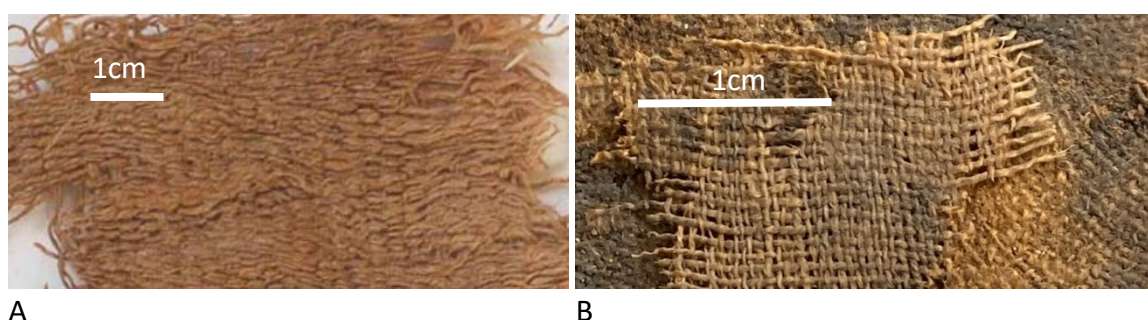


Figure 104. Comparison of a linen sample from the literature Letellier-Willemin (2020) (A) with a bandage piece from the cranial region of the mummified head 28.

The Egyptian mummified head with the inventory number **2478** has a very special appearance: the skin is almost completely preserved and possibly impregnated with resin or something similar, which caused a shiny black effect. Additionally, some areas around the mouth and the right eye contain gold applications. The case number 2478 does not entirely match any period. Whereas its resin treatment points to the First Intermediate Period onwards, its absence of excerebration suggests the Second Intermediate Period. The Second Intermediate Period however seems unlikely for the case 2478 because at that time usually cranium, eyes or mouth were stuffed with linen rolls. Further studies on the used embalming material as well as a C14 analyses should be carried out on this case to elucidate the period to which this mummified head can be assigned.

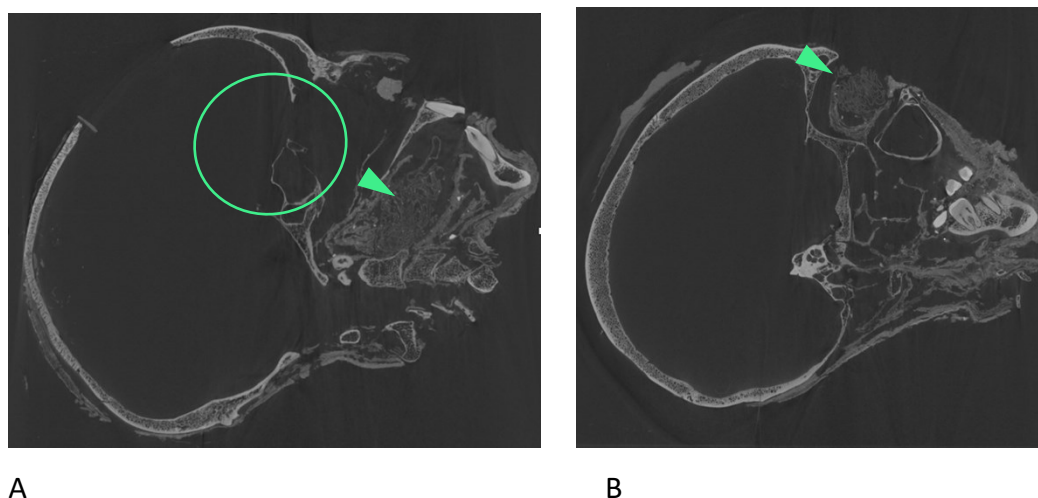
The mummified head with the inventory number **5043** shows some cracking on the forehead indicating stage 1 on bone weathering. At this white cracked area, the bone probably has been exposed to sun some time after mummification but well before this mummified head reached the NHMW. However, skin is preserved on most parts and also bandage remains are visible. Neither brain remains nor damage in the nasal region, which would indicate excerebration, could be detected.

Fortunately, a sample could be taken from this case and ^{14}C dating resulted in 796 – 571 BC with 95% probability. This allows to conclude that this individual most likely lived sometime between the late Third Intermediate Period (1069 – 656 BC) and the early Late Period (664 – 332 BC).

According to literature, characteristic mummification features of these periods are artificial or stuffed eyes, body painting, cartonnage wrapping, impregnation of the body with natron and/ or resin, subcutaneous packing (during the Third Intermediate Period) and excerebration through the trans-nasal region (during the Late Period) (Badr, 2015; Cooney, 2012; Loynes, 2015). Curiously, however, none of these feature combination matches with this skull. Neither artificial eyes nor stuffing material or body painting could be found on this mummy; which would exclude the Third Intermediate Period. Only the shiny black surface of this mummy could be due to the use of resinous material

and would correspond to the Third Intermediate Period. The absence of excerebration on the case number 5043, on the other hand, also makes the Late Period less probable. Thus, further investigations such as chemical analyses of embalming materials on the surface of the mummy are necessary to be carried out for this case to better understand the historical context of this case. On the other side, perhaps, this case may illustrate that mummification methods were not as homogeneous at a given period of time, as originally supposed (Saleem & Hawass, 2013).

The Egyptian mummified head **5877** is in a very bad preservation condition with fragments of soft tissue and embalming material falling off all over the surface. This mummified head can probably be assigned to between the Late Period (664 - 332 BC) and Roman Period (30 BC - 394 AD). Characteristics that match this time frame are the excerebration through the nose (Late Period) and stuffing with linen bundles of the mouth and eyes (Roman Period) (Loynes, 2015). Figure 105 shows a μ -CT slice of the mummified head 5877 that shows the linen packing in the region of the mouth and the eyes as well as the destroyed nasal region due to possible excerebration. Further studies on the used embalming material as well as a C14 analyses should be carried out on this case to elucidate the period to which this mummified head can be assigned.



A **B**
Figure 105. μ -CT slice from two different sectional views from the mummified head 5877 shows the stuffing material inside the mouth (A) and eye (B) (green arrow). The green circle indicates the destroyed cribriform plate and crista galli.

The soft tissue of the mummified head **9200** is in a good condition, with eyelids, nose, mouth and ears very well preserved. On the outer surface, there are no remains of bandage material. Neither brain remains nor damage in the nasal region, which would indicate excerebration, could be detected. But there are brain remains visible inside the skull. An assignment to a specific time period is not possible for this mummy, as there are no matching mummification features to the respective periods. Above all, the fact that no remains of bandages are visible makes a chronological assignment even more difficult. It is possible that this mummy was wrapped in bandages and linen at an earlier time, but they could have been removed at a later point in time. This could have been done for better visual observation and/ or presentation purposes. No notes or archival material on the realization of such procedures were found in the NHMW.

The soft tissue of the mummified head **14726** is very well preserved. However, there are no remains of bandage material. But this skull shows much stuffing material inside the skull. The stuffing material in the cranium may have been soaked in resinous material to dry out the inside of the skull, as well as the brain, instead of removing the brain, since dried brain remains has been detected. Additional stuffing material in the mouth may have been used to keep the tongue in position and also for stuffing the cheeks to maintain the shape of the face. Figure 106 shows that the cranium as well as the mouth and the cheeks are tightly packed with textile material.

There is also a ¹⁴C date available for this head, indicating this person lived sometime between 1217 and 1020 BC with 95% probability. This, in turn, allows to assign this case to the late New Kingdom (1539 – 1077 BC) and/or the very early Third Intermediate Period (1069 – 656 BC) (Hornung et al., 2006; I. Shaw, 2003).

According to literature (Aufderheide, 2003; Badr, 2015; Bianucci et al., 2008; Cooney, 2012), characteristic mummification features of these periods are impregnation of the body with natron and/ or resin (during both periods), stuffing of the body cavities with resin soaked linen and excerebration through the trans-nasal region (during the New Kingdom Period) and artificial or stuffed eyes, body painting, stuffing of the body

cavities with resin soaked linen and subcutaneous packing (during the Third Intermediate Period).

However, again only a few characteristics of the case 14726 correspond with the information provided in the literature, where during Late Period the bandage packing of the cranium and the mouth part as well as the trans-nasal opening was typical (Loynes, 2015). However, the brain of case 14726 was not removed through a trans-nasal opening, but was stuffed with bandages, probably soaked with natron or resin to accelerate the desiccation process. Thus, the Late Period mummification methods seem not to have been applied to the case 14726. According to the mummification characteristics, thus, this mummy would fit better into the Second Intermediate Period. According to the literature (Šefčáková et al., 2005), during this period the brain was not removed, but stuffing through the nose took place. The stuffing of the oral cavity with linen rolls, which was also practiced during this period, corresponds very well to the mummy with inventory number 14726. It is possible that the ^{14}C date determination resulted in a slight overestimation of the age, because in this case tissue remain was used for ^{14}C analyses instead of a bone fragment. Figure 106 shows a $\mu\text{-CT}$ slice of the mummified head 14726 with evidence of stuffing material.

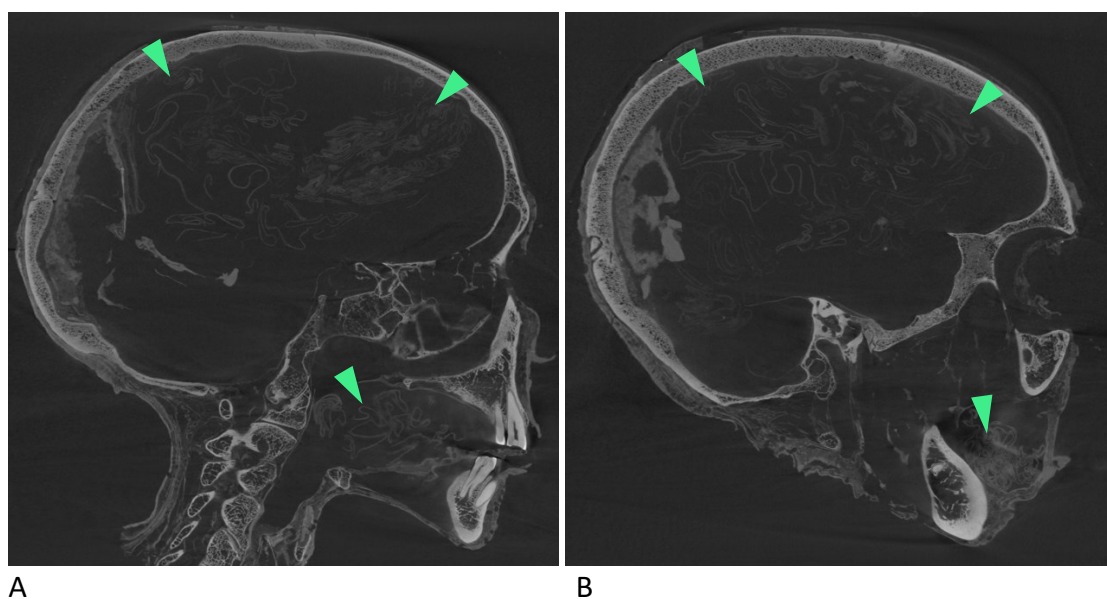


Figure 106. $\mu\text{-CT}$ slice from a sagittal sectional views from the mummified head 14726 shows the stuffing material inside the skull (green arrow).

The last Egyptian mummified head discussed herein is that of the individual with the inventory number **15378**. This mummy is completely wrapped in bandages and the underlying soft tissue remains are still well preserved. The is covered with several layers of bandage strips which showed two different mesh sizes. The bottommost bandage strips have a finer mesh, while the uppermost bandages in the facial region have a coarser mesh.

These findings fit very well with the descriptions by Letellier-Willemin (2020). In this paper, the most common density of textiles used for mummy bandages during the Ptolemaic Period was between 22 and 28 threads per centimeter, but textiles with 40 threads per centimeter were also found quite often. In the case of mummy 15378, the two different mesh sizes were around 18 and around 42 threads per centimeter, thus suggesting that this individual lived during the Ptolemaic Period (332 – 30 BC).

Also the fact that the mummified head 15378 probably shows excerebration due to the destroyed nasal region and that no other noticeable mummification features were found fits very well with the mummification features of the Ptolemaic Period. This is, because characteristic features of this period are the excerebration through the trans-nasal route and the absence of eye and mouth filling, as well as subcutaneous packing (Loynes, 2015).

4.5.2 The Peruvian mummified head

In Peruvian mummies of the NHMW, no insect damage could be seen on the mummified head or on the skeletonized skulls. There are also no specific cases in the literature describing insect damage on Peruvian or South American mummies.

Unfortunately, there is only one Peruvian mummified head at the Natural History Museum. All other Peruvian mummy skulls have been demummified, making it no longer possible to assign them to a time period by comparing them with literature. Only in the case of another already demummified skull an assignment to a time period is possible on the basis of ^{14}C data.

The Peruvian mummy with inventory number **2876** looks very special. It is the only mummy that still had its hair attached to the head. In this case a sample could be taken and send for ^{14}C dating, indicating this individual lived in the time range 1322 – 1419 AD with 95% probability. This suggests this individual lived during the Late Intermediate Period (1000 – 1476 AD). From a geographical point of view, the Chimu culture would fit best to the mummified head 2876, as the place Chimu is only about 50 km away from Viru, the place of origin of mummy 2876. In the Chimu culture, the mummies were covered with layers of fine cotton (Cowie & Johnson, 2002). This feature also fits with the described mummy, which is covered with a wool-like yellowish fibre. However, also in this case, more studies are necessary to better assign it to this cultural period.

For the already skeletonized mummified head **2875** a sample could be taken for ^{14}C dating. These results revealed that this individual probably lived between 893 – 992 AD with 95% probability, which corresponds to the Late Middle Horizon Period (600 – 1000 AD - (Cockburn et al., 1998)).

Although the skeletonized skull 2875 and the mummified heads with the inventory number 2876 originate from the same local site (Viru, province of Libertad) and also came to the Natural History Museum through the same collector (Charles Wiener) at the same time (inferred on the basis of the consecutive inventory numbers - 2871 to 2877), they resulted to have different datations. Due to the fact that the consecutive inventory numbers 2871 to 2877 come from the same area of origin and were all collected by Charles Wiener, conclusions could have been made that these skulls/heads are of similar age. However, the ^{14}C data of the two inventory numbers 2875 and 2876 disproved this assumption. This is not astonishing since Viru is not only the name of a valley in Peru but also an archaeological culture (according to Quilter (2013) also known as Gallinazo). Since it is not clear by the inventory book inscription to what exactly “Viru” refers, and the Viru valley was inhabited throughout long periods of time, human remains dated to different time periods are indeed expected.

4.5.3 The New Hebridean “mummified” head

One mummy skull, with the arbitrarily given number 5, could not be assigned to any entry in the inventory book; thus no information about the origin of this skull was known until now. On the basis of its external characteristic features, however, the skull shows features that allow assigning it herein to the New Hebrides. Comparing this skull with the different treatment of the dead observed in ancient Melanesia until today, it is possible to find various characteristics very similar to those found in the literature on mummies from the New Hebrides (Cockburn et al., 1998).

However, it must be remembered that the methods used to treat the dead in the New Hebrides cannot be called mummification techniques (Flower, 1882). In the New Hebridean the mortuary rituals do not include real mummification techniques with the aim to preserve soft tissue, as the soft tissue is intentionally removed before the skull is processed and prepared to more or less resemble a head with face, eyes, ears and a mouth (Flower, 1882). However, in the specific case number 5, the designation "mummy head" is retained for this skull, as there are still some remains of soft tissue on the skull, which were probably not removed carefully enough during the preparation process. As human remains with exotic features as those described for this individual were eagerly collected for European museums in the nineteenth and also twentieth centuries, and such collection “items” were also sold for quite good prices, it cannot be excluded that case number 5 is a forgery (Eccles, 2015).

4.6 Limitations of this work

Our results and findings contain some limitations.

First of all, due to time constraints, no analysis of the complete mummy collection of the NHMW could be carried out. Therefore, a selective choice was made. These selection criteria are described in detail in chapter 2.2.

Second, not all methods were possible to be carried out on each of the cases in a systematic way. Some features of the mummified skulls could only be examined on the basis of the CT data, whereas the features of the already skeletonized skulls could be examined directly on the skull.

In addition, for financial reasons, it was not possible to carry out a ^{14}C analysis on every individual examined.

Due to the very small number of cases, no large statistical studies could be carried out here. For this reason, this work always refers to case studies and not to populations (when talking about Peru, Egypt or the New Hebrides). Contextualization of the regional “groups” with the literature is by no means exhaustive, but only intended to roughly check the plausibility of the provenance results

For discussion on the historical time periods to which the mummified heads could be assigned, no attempt was possible to be carried out to critically analyze the extensive literature on the chronology of the cultural periods in Peru, Egypt or the New Hebrides. That was also not the aim of this thesis.

Conclusions

Among the 24 cases of (earlier) mummified heads analyzed herein, for four of them, all nine multi-method variables could be adequately described and contextualized. These nine multi-method variables include archive research and place of origin, sex, age at death, dental and oral health, modifications of the living, palaeopathology, taphonomy, imaging (CT and/ or x-ray) and C14 dating. These four cases refer to the following inventory numbers: 2875, 2876, 5043 and 14726. An imaging method was not necessary for skull 2875, as this skull was already completely skeletonized and therefore all multi-method variables could be sufficiently determined.

For the remaining 20 cases at least seven of these variables could be adequately analyzed and investigated. All individuals could be assigned to an age class, and it was also possible to sufficiently investigate the dental status and oral health, palaeopathologies, modifications made during life and taphonomy for all of them. Due to time constraints, dating and computer tomographic images for more detailed analyses could not be carried out on all individuals.

The non-invasive method of CT scanning of the wrapped mummies and subsequent 3D visualization is a very important tool for the non-destructive investigation of palaeopathology and taphonomy. This method allows to visualize characteristics that are not visible to the naked eye, especially due to the overlying soft tissue or embalming material. Furthermore, insights into the heads can be achieved that could not be obtained even with unwrapped skulls. This includes visualizations of the internal parts of the skull for the analysis of cultural modifications and diseases, but also teeth, and especially tooth roots, can be examined for precise age at death analyses.

CT-scanning furthermore allow 3D printing of skulls and mummified heads, that can represent valuable didactic material and interesting items for expositions. This is specially so if considering the actual recommendations not to expose human remains (Deutscher Museumsbund e.V., 2021).

Nevertheless, with the help of provenance research, visual examination, CT visualization and four ^{14}C samplings, all mummies could be assigned to a country or more specific region or archaeological site of origin. Three cases could be assigned to a specific chronological horizon and four ^{14}C dates could be retrieved. In addition, interesting palaeopathological findings, such as cribra orbitalia, porotic hyperostosis and trauma were discovered only using CT scans- stressing the importance of this method while studying mummified remains.

With the help of this study, the first analyses of the Egyptian, Peruvian and New Hebridean mummies housed in the Natural History Museum Vienna, which had not been studied to date, could be carried out. However, this is only the first step towards analyzing them. Some of the wrapped mummified heads are still waiting for the ^{14}C results and further sampling for additional analyses, such as chemical, isotopic and eventually also aDNA analyses. Furthermore, herein the part of the mummy collection of the NHMW was examined that consists only of (earlier) mummified heads, did not yet have any published preliminary investigations and does not contain any ethically questionable cases. This means that there are still 24 mummified heads and other body parts in the Anthropological Department of the Natural History Museum in Vienna, that are waiting to be examined in order to reveal the mysteries behind these wrapped remains.

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