

NEW INSIGHTS ON MUMMIFICATION TECHNIQUES DURING ANCIENT EGYPT'S MIDDLE KINGDOM PERIOD (2055-1782 BC) USING NON-DESTRUCTIVE CT-SCANNING OF THE MUMMY OF LADY AMANIT, PRIESTESS OF HATHOR

BY

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ABSTRACT

رؤى جديدة لتقنيات التحنيط في عصرالدولة الوسطى في مصر القديمة (1782-2055 ق.م.) باستخدام التصوير بالأشعة المقطعية للمومياء السيدة أمانيت، كاهنة حتحور.

[AR] في القرن التاسع عشر وأوائل القرن العشرين كانت طرق فحص ودراسة المومياوات المصرية، تعتمد على الفحص البصري والطرق غير العلمية المدمرة. ومع تقدم التكنولوجيا في القرن الحادي والعشرين، ظهرت طرق فحص علمية غير تدميرية مثل الفحص بالأشعة المقطعية CT. وتهدف الدراسة إلى إعادة فحص المومياوات وإعادة قراءتها بناءً على أدلة علمية واضحة، ودراسة مدى الارتباط بين الفحص البصري بالفحص بالأشعة المقطعية CT، حيث تم تقسيم جسم المومياء إلى مناطق مختلفة لتتبع التغيرات المورفولوجية بعد التحنيط، حيث كشف الفحص البصري عن مظاهر التلف خارج جسم المومياء، بينما كشف الفحص بالأشعة المقطعية عن حالة الجسم الفيزيائية في الهيكل الداخلي للمومياء. توصلت الدراسة إلى تطابق معلومات الأثرية القديمة في طرق التحنيط في الدولة الوسطى وخاصة في العصر الحادي عشر، حيث استخدم المحنطون طريقة الحقن باستخدام زيت الأرز أو زيت العرعر لإزالة الأحشاء الداخلية. كما أظهرت الدراسة وجود بقايا أعضاء داخلية في تجويف الصدر والبطن. وتأكدت سلامة الحجاب الحاجز دون أي تلف. وقدمت الدراسة طريقة لفحص المومياوات تتفق مع الأساليب العلمية دون أن تتسبب في تلف المومياء. كما أشارت الدراسة إلى قلة عدد المومياوات التي تعود إلى الدولة القديمة مقارنة بالمومياوات في الفترات اللاحقة، نتيجة للسرقة والتعرض للتلف خلال فترات الاضمحلال. وأشارت أيضاً إلى أن التحنيط في تلك الفترة كان مقتصرًا على طبقة محدودة من المجتمع.

[EN] The examination and study of Egyptian mummies in the 19th and early 20th centuries relied on visual inspection and non-scientific destructive methods. However, advancements in non-destructive examination techniques, such as Computed Tomography (CT) scanning, have necessitated a re-examination and reinterpretation of mummies based on confirmed scientific evidence. This research aims to reassess and reinterpret mummies using reliable scientific evidence, while also studying the potential correlation between visual examination and CT scanning. This scientific paper presents a contemporary reading of mummification techniques in ancient Egypt through the examination of Lady Amanit's mummy from the 11th dynasty of the Middle Kingdom. The research employs a comparative approach between visual examination and CT scanning, dividing the mummy's body into regions to trace morphological changes post-mummification. Visual examination detects external deteriorations, while CT scanning reveals the internal physical condition, the study aligns with archaeological information on mummification techniques in the Middle Kingdom, indicating the use of injection methods for organ removal. Remnants of internal organs were found within the chest and abdominal cavities, with the intact diaphragm confirming its undamaged state. The non-invasive examination method aligns with scientific approaches without causing harm to the mummies. Moreover, the study highlights the scarcity of mummies from the Old Kingdom compared to later periods, primarily due to theft during periods of decline. It also suggests that mummification during this time was limited to a specific social class. This research provides new insights into mummification techniques and contributes to the field of Egyptology by combining visual examination and CT scanning, resulting in a comprehensive understanding of ancient Egyptian mummies.

KEYWORDS: CT scanning, ethmoid bone, middle Kingdom, mummification technique, mummy of Amanit, Natron, Tattooed mummy, visceral orifice.

I. INTRODUCTION

Mummification was a complex and highly ritualized process of preserving the bodies of the deceased in ancient Egypt. This practice evolved through several important stages over thousands of years. In the earliest stages of Egyptian civilization, around 5000 BC, the dead were buried in sandy shallow pit graves, which allowed for rapid dehydration/desiccation of the soft tissues. However, as time passed, the Egyptians began to develop techniques to slow down or prevent the decomposition of the body, to better preserve it for the afterlife¹. The development of mummification in ancient Egypt can be divided into two distinct techniques. The first technique, known as natural mummification, involved wrapping the deceased in linen and placing the body in a shallow pit in the desert to desiccate naturally in the dry, hot climate of Egypt.

The second technique, known as anthropogenic or artificial mummification, involved the use of natron, a naturally occurring salt that was used to dry out the body and prevent decay, with or without excerebration of the brain and/or evisceration of internal organs. The body was then wrapped in linen and placed in a coffin or sarcophagus². Tracking the development of artificial mummification throughout ancient Egyptian history is complicated as there is no direct material evidence to trace this development and the mummification method itself³. Historians in the past, such as Herodotus or Diodorus Sicily, could only hypothesize about the mummification process as they were not present during it.

The recurrent failure of preserving the soft tissues with the techniques used during the Archaic Period (3100 - 2686 BC), also known as the early dynastic period (1st and 2nd dynasties) following the unification of Lower and Upper Egypt, inspired the Old Kingdom embalmers with some successful modifications. During this period, for example, linen wrappings soaked in resin were used to create molds of the face, hands, and feet of the mummy⁴. During the Old Kingdom (2686-2181 BC), mummification became a specialized art form, and was believed to be restricted to the king and royal family before being extended to the nobility.

In the Middle Kingdom (2055-1650 BC), mummification was not restricted to the kings and their families⁵, but became available to members of the middle class⁶. Embalmers refined the technique of mummification to preserve the soft tissues of the body using natron salt in solid form and injected the body from the anus with cedar or juniper oil⁷. During the New Kingdom (1550-1070 BC), mummification reached its peak of sophistication, with embalmers developing new techniques for preserving the body and creating elaborate funeral rituals. The body was wrapped in many layers of linen, and a death mask was placed over the face to protect the features of the deceased⁸.

¹ TACONIS 2005: 35-51.

² BRIER & WADE 1997: 89-100.

³ DAVID 1999: 543-546.

⁴ DAVID 2000: 372-389.

⁵ TAYLOR 2001A: 47.

⁶ DAWSON 1927A: 40-49.

⁷ DAWSON 1929: 61-64.

⁸ GRAJETZKI 2003: 231-236.

The mummification process did not have specific fixed rules, but rather was subject to the skill of the embalmer, the state of the body itself, and the availability of raw materials used in the process of mummification. This suggests that the mummification process was highly individualized and tailored to the specific needs of each body, rather than following a standardized set of procedures.

1. Mummification Studies in the 20th Century AD

The physical examination and study of ancient Egyptian mummies has gone through several iterations since the classical era of writers such as Strabo and Herodotus. Initially, techniques of mummification were observed during the theft of valuable antiquities preserved inside the mummy, and then mummy examinations became a means of attracting audiences and generating financial gain, such as the public examination performed by Margaret Murray⁹ (1863-1963) in October 1908 [FIGURE 1]. Although Murray's event was both scientific and a sort of performance before an audience, the reality is that these performances directly introduced the field of Egyptology and mummy science, creating a passion for scientists to study Egyptian mummies¹⁰. In the 20th century AD, scientists from various fields such as physics, chemistry, and anthropology turned their attention to the study of embalming techniques in ancient Egypt¹¹, leading to the beginnings of true scientific discovery about ancient Egyptian mummification.



[FIGURE 1]: Margaret Murray's unwrapping of the mummy Khnum Nakht in front of an audience at the Manchester Museum, University of Manchester, Early 20th century AD. HELMY 2012: 125.

The use of radiography to study Egyptian mummies dates back to the mid-1890s, coinciding with the discovery of X-rays by Roentgen. However, its early adoption was hindered by the logistical challenges of transporting mummies to hospitals for

⁹ BIERBRIER 2012: 393-394.

¹⁰ IKRAM & DODSON 1998: 132-140.

¹¹ GOYON & JOSSET 1988: 34-38.

examination, as noted by Grafton Elliott Smith in his account of transporting the pharaoh Thutmose IV through 1904 Cairo¹².

In 1931, a significant radiographic study of Egyptian and Peruvian mummies was conducted at the Field Museum in Chicago by Moodie, but the widespread use of radiography in mummy studies did not occur until the advent of portable X-ray equipment in the 1960s¹³. This technological advancement facilitated more accessible and frequent radiography of mummies, leading to a greater understanding of their anatomy, health, and cultural context¹⁴.

In 1977, computed tomography (CT) scanning was introduced as an alternative or complementary technique to standard plain radiography for examining Egyptian mummies. The first CT scans of mummies were conducted in both Toronto, Canada and Tübingen, Germany. However, not all researchers immediately recognized the value of CT scanning, and some continued to prefer standard radiography over CT. This was partly because the medical and anthropological information of interest to doctors and radiologists was initially not as apparent on CT images as it was on plain radiographs¹⁵.

Despite advances in CT techniques, the full potential of CT scanning in mummy studies was still not fully appreciated as evident from the fact that CT scans of mummies conducted at the Carnegie Museum in Pittsburgh, PA in 1986 were not mentioned in the published catalogue, which only provided interpretations of standard X-rays¹⁶.

Egyptologists, archaeologists, anthropologists, and conservators are particularly interested in information on mummification technique. CT scanning is especially useful in studying certain elements of the mummification process, such as brain removal, abdominal incision, visceral removal and replacement, body packing, and wrapping techniques. Thin cross-sectional slices provided by CT are ideal for this purpose¹⁷.

2. Mummification in the Middle Kingdom, 11th and 12th Dynasties

The mummy of Lady Amanit, a priestess of Hathor, is one of the most important tattooed mummies from the 11th dynasty found in Deir el-Bahari. Lady Amanit, whose title can be translated as «King's Favorite Ornament» was discovered in 1891 AD by Eugene Grébaud, a French Egyptologist, near the Temple of Mentuhotep II at Deir el-Bahari, entombed in a wooden coffin. Two other tattooed mummies, described as Hathor dancers in the court of King Mentuhotep II, were also found at Deir el-Bahari in pits 23 and 26¹⁸. Lady Amanit's mummy is currently preserved in the Egyptian Museum in Cairo, while the current whereabouts of the two Hathor dancers is not known¹⁹.

¹² SALEEM et Al. 2012: 179-232.

¹³ BUCKLEY et Al. 2017: 539-550.

¹⁴ SATO et Al. 2015: 256-263.

¹⁵ GRÖNING et Al. 2013: 256-267.

¹⁶ RÜHLI ET AL. 2012 :509-510.

¹⁷ KALLALA et Al. 2014: 309-322.

¹⁸ DARESSY1893: 166-170; WINLOCK 1942: 31, 33; ROEHRIG 2015: 527-536.

¹⁹ SEIPEL 1996: 41-45.

These mummies provided an ideal model for studying the methods and techniques of mummification in the 11th dynasty²⁰. In 1921, a renowned British anatomist and anthropologist, Douglas E. Derry, gave a detailed description from a medical and chemical point of view of the embalming technique used to preserve the bodies of the queens and princesses of the Middle Kingdom, 11th dynasty, «there have been attempts to remove parts of the abdominal and pelvic contents using natural orifices»²¹. The discovery of stained linen rolls used as swabs and sacks of natron buried with some mummies suggests that embalmers tried to preserve the bodies by using natron salt, including the mummy of Amanit [FIGURE 2], which was studied in this research.

The method of mummification practiced during the Middle Kingdom Period was described by Herodotus as: «no incision or resection of the bowel was made, but cedar oil is injected with a syringe into the body through the anus which is then turned off to prevent liquid from escaping. Then the body is pickled in natron, for the exact number of the day, the last thing the oil is drained»²². The embalmer used beeswax to seal body openings (anus) to prevent leakage of cedar oil after injection²³. The cedar oil mentioned by Herodotus was most likely not true cedar oil but likely juniper oil²⁴, which was used in medicine at the time and mentioned in the medical papyri²⁵. In the cases of non-royal mummies, it was possible to replace the expensive (imported) juniper oil with cheaper local alternatives such as radish seed oil²⁶. Dawson believes that evisceration via the mouth was not technically possible by following the steps mentioned by Herodotus. However, according to Dawson, juniper oil or any other liquid could have delayed the autolysis process for a short time to allow embalmers to prepare for the dehydration process²⁷.

II. MATERIALS AND METHODS

The mummy of Lady Amanit, a priestess of Hathor from the 11th dynasty, currently resides in the Egyptian Museum in Cairo, lying on a modern wooden bed outside her coffin.



[FIGURE 2]: Lady Amanit's Mummy, 11th dynasty. The Egyptian Museum in Cairo © Photo taken by Ibrahim Badr

²⁰ AUFDERHEIDE 2003: 228-229.

²¹ DERRY 1942: 240-265.

²² SÉLINCOURT 2003: 324-335.

²³ RAVEN 1983: 7-47.

²⁴ LUCAS 1931: 13-21.

²⁵ KAMAL 1967: 256.

²⁶ GHALIOUNGUI 1963: 162-163.

²⁷ DAWSON 1929: 125-127.



[FIGURE3]: Lady Amanit’s mummy being examined in a mobile 6-slice CT scanner, which uses X-rays to create detailed images of the body © Photo taken by Ibrahim Badr

| Physician | Scan | KV | Mass/ref | CTDLvoL | DLP | TI | eSL |
|---------------------|------|-----|----------|---------|------|------|-----|
| Pation position H- | | 130 | | | | | |
| Topo gram | 1 | 130 | | | | 11.0 | 0.5 |
| Head | 2 | 130 | 130 | 17.63 | 416 | 0.8 | 0.5 |
| Control scan | 3 | 130 | 45 | 9.85 | 1 | 0.8 | 1.0 |
| Dental | 4 | 130 | 45 | 12.36 | 148 | 0.8 | 1.0 |
| Operation body scan | 5 | 130 | 58/124 | 7.70 | 506 | 1.5 | 1.0 |
| Add scan | 6 | 130 | 79/124 | 10.8MAS | 2463 | 1.5 | 0.5 |

[TABLE 1]: System operating conditions of CT Scanning when examining the mummy of Lady Amanit at the Egyptian Museum in Cairo © Done by the researchers

III. RESULTS

1. Visual Examination of Lady Amanit’s Mummy

A. Visual Examination of the Head

The visual inspection of the mummy of Lady Amanit, a priestess of Hathor, revealed several important observations. Henna was used on the nails of her hands, and remnants of the henna can still be seen today [FIGURE 2]. This suggests that the embalmer placed a great emphasis on the external appearance of the mummy, perhaps to ensure that the deceased appeared as attractive and youthful as possible in the afterlife.

The visual examination of Lady Amanit’s head revealed several important details about its state and external appearance. Her hair was partially separated from the scalp, with the back of the hair still adherent to the scalp which was also subjected to fungal and insect attacks, likely contributing to its weak and dilapidated state. The skin of the forehead was separated down to the eyes, especially the left eye. The left eye has a complete separation of the skin layer of the eyelid, with significant insect and fungal attack that led to almost complete erosion of the left eye area of the mummy [FIGURE 4]. The mouth was found to be open with the tongue sticking out, likely due to postmortem relaxation of the jaw. The right side of the mummy's face showed significant biological

damage, with erosion, cracks, and tunnels caused by insect invasion. The teeth were well preserved with moderate occlusal wear [FIGURE 5].



[FIGURE 4]: Red circle shows separation of the outer layer of the scalp from the skull
© Photo taken by Ibrahim Badr



[FIGURE 5]: A. The yellow square shows tunnels caused by insect invasion, B. Teeth shows moderate occlusal wear © Photo taken by Ibrahim Badr

B. Visual Examination of the Thorax, Abdomen and Pelvis

The exterior description of the thorax and abdomen of Lady Amanit's mummy reveals several important details about the state of preservation and the mummification process used. The chest and abdomen are in good condition, indicating that the mummification process was successful and close to the quality of mummification from the New Kingdom Period and the Third Intermediate Period.

The back of the mummy's body also appears to be in good condition, but was subjected to insect attack²⁸, which led to the elimination of the skin layer and the appearance of only the ribs in this region [FIGURE 6]. Some holes are scattered on the mummy's abdomen, likely due to an old insect infestation. Upon examination using a manual lens, there is no opening for the viscera on either the left or right side of the body, indicating that the embalmer did not extract the viscera by opening the body from the left side as was later done during the New Kingdom Period and Third Intermediate Period²⁹ [FIGURE 7].

²⁸ IKRAM et Al. 2012: 55-61.

²⁹ RÜHLI et Al. 2007: 243-244.



[FIGURE 6]: Lady Amanit's mummy. The yellow circle in the figure highlights the exposed ribs of the chest due to insect damage to the skin layer © Photo taken by Ibrahim Badr



[FIGURE 7]: Lady Amanit's mummified body, red rectangle indicates the absence of an opening for extraction of the viscera. The yellow circle indicates scattered holes on the lower chest consistent with old insect infestation © Photo taken by Ibrahim Badr

Lady Amanit's mummy was adorned with a *menat* necklace, worn by the clergy of Hathor, as well as multiple pectoral necklaces and finger rings. The multiple necklaces that cover the neck and upper chest were found to be in poor condition. Some parts of the necklaces were detached from their original positions and entirely covered with a layer of salt³⁰. The presence of the natron salts led to the complete separation of parts of the necklaces. The head of the mummy was completely separated from the body, with the only link being the weak and dilapidated necklaces [FIGURE 8]. Alongside her mummified remains, the jewelry and tattooing described here are the subject of an in-depth ongoing study of the burial equipment and tomb of the Lady Amanit.



[FIGURE 8]: Necklaces on Lady Amanit's mummy, which are in a poor and deteriorated state © Photo taken by Ibrahim Badr

³⁰ HAWASS et Al. 2001: 993-1001

Amanit's mummy had tattoos³¹ on her left shoulder and breast consisting of a row of dots encased in two lines and on her right arm below the elbow, approximately nine rows of dotted tattoo marks. The tattoos on her abdomen and pelvis were in three groups.



[FIGURE 9]: Tattoos on Amanit's abdomen and pelvis, highlighted by a yellow circle © Photo taken by Ibrahim Badr

Group one: midline just below the zyphoid, consisted of a rectangular pattern of six lines made up of three dashes each. Group two: midline just above the navel, consisting of a rectangular pattern of dots and dashes. Group three: below the navel is a group of marks, consisting of multiple dashes, covering virtually the entire abdominal wall in the suprapubic region [FIGURE 9]. In addition, a tattoo was in the middle of her right thigh in the design of multiple diamond shapes composed of dots³². All tattoos appeared dark blue in color. Scarification in the form of three horizontal parallel lines was also evident in the groin area.

C. Visual Examination of the Arms, Legs and Feet

The exterior description of the arms, legs, and feet of Lady Amanit's mummy reveals several important details about the state of preservation. The right arm is broken at the mid humerus and is currently located between the legs. The left arm is missing. The skin over the legs is well preserved except for evidence of old insect infestation [FIGURE 10]. The mummy has lost four toes on the left foot, which suggests that the body may have been damaged or disturbed at some point in its history [FIGURE 11]. Traces of metal accessories placed by the embalmer before completing the drying of the mummy's body from the resin may also be found³³. An ankle bracelet placed on the mummy is preserved as a mark on the skin. It has since been dropped off or removed [FIGURE 11].

³¹ KEIMER 1948: 8-13, PLS.1-5.

³² DARESSY 1913: 97-109.

³³ LEEK 1969: 112-116.



[FIGURE 10]: Close-up view of Lady Amanit's mummified pelvis and legs. Red rectangle indicates the absence of an incision for the viscera extraction hole on either the left or right side of the body. Two yellow squares indicate the quality of the mummification of the right and left legs of the mummy
© Photo taken by Ibrahim Badr



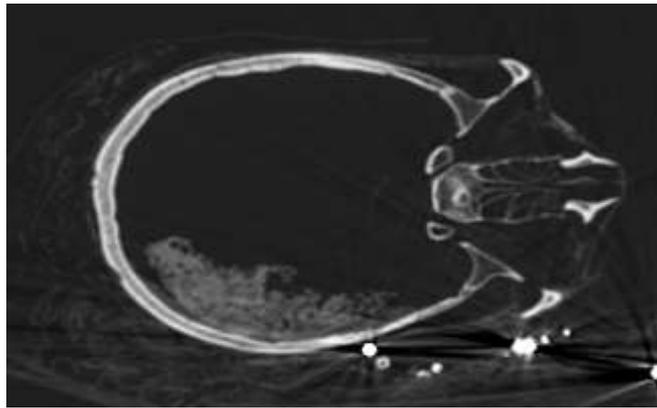
[FIGURE 11]: Close-up view of the feet of Lady Amanit. Yellow circle indicates the loss of four toes from the left foot. Red square indicates the presence of traces of metal accessories (ankle bracelets) that are no longer present © Photo taken by Ibrahim Badr

2-CT Examination of Lady Amanit's Mummy

A. CT Findings of Lady Amanit's Skull.

The CT Scanning³⁴ of Lady Amanit's skull revealed several important details about the internal structures and state of preservation. There are no fractures involving the skull. There are no defects in the ethmoid bones nor the cribriform plate to suggest attempted excerebration. The brain is visible inside the cranial cavity [FIGURE 12]. This suggests that the mummification process during the Middle Kingdom may not have been as advanced as previously thought, evidenced by the fact that Lady Amanit's brain was not removed.

³⁴ Randall et Al. 2013: 1211–1222.



[FIGURE 12]: Lady Amanit's mummified skull shows absence of any fractures or damage to the skull and no fractures of the Ethmoid bones. The brain is present © Photo taken by Ibrahim Badr

B. CT Findings of the Neck and Torso

CT scanning of the neck and thorax found that there was a separation between the head and body of Lady Amanit's mummy. There are disruptions of her spine at C5-6, T2-3 and T5-6, likely postmortem, resulting in separation of her head from her body and rotation of her head to the left.

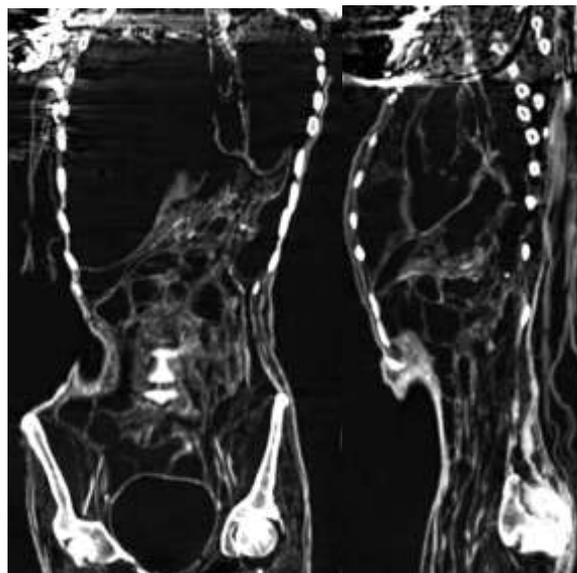
The only link between the head and body are the multiple necklaces that extend from the bottom of the skull and surround her neck and chest, as shown in [FIGURE 13]. This confirms the findings from the external examination of the mummy, which revealed that the head was completely separated from the body, and the only link between them is the multiple weak and deteriorated necklaces.



[FIGURE 13]: Multiple necklaces surround the base of the neck and upper chest of Lady Amanit's mummy. The head is separated from the body due to multiple separations of the cervical and thoracic vertebrae © Photo taken by Ibrahim Badr

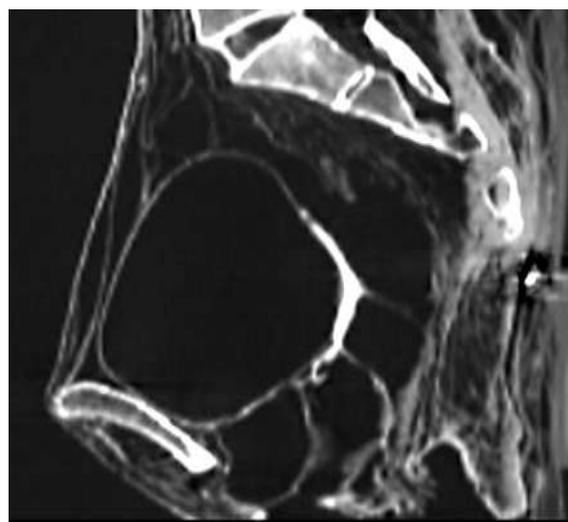
Through the CT scanning examination, it was found that the chest cavity showed remnants of heart, mediastinum, and pleura. The abdominal cavity showed bowel wall remnants. The pelvic cavity showed bladder, vaginal and rectal wall remnants [FIGURES 14-15]. These findings suggest that the embalmer used the second method of mummification, which involved injecting one of the oils used in ancient Egyptian periods³⁵ such as cedar or juniper oil to evacuate the contents of the bowel.

However, the chest and abdomen were completely devoid of permanent filling materials that were usually used in later periods for the mummification process. However, the CT scanning revealed that the internal soft tissues and bones were preserved, indicating that the embalming process was successful in preparing the body for the afterlife³⁶.



[FIGURE 14]: CT scan showed that the chest cavity contains remnants of the heart, mediastinum, and pleura. The abdominal and pelvic cavities showed bowel, bladder, vaginal and rectal wall remnants

© Photo taken by Ibrahim Badr



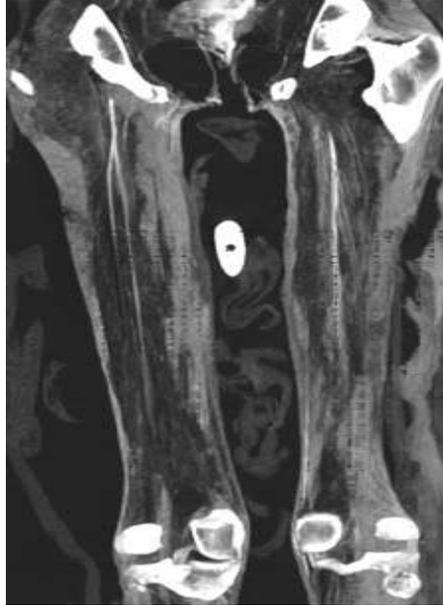
[FIGURE 15]: CT scan of the pelvis showed bladder, vaginal and rectal wall remnants © Photo taken by Ibrahim Badr

³⁵ ELADANY 2012: 70-73.

³⁶ DAVID 2009: 16.

Radiological Description of the Legs and Feet

The soft tissue of the legs is well preserved. Increased density is seen in the periphery of the soft tissues consistent with uptake of natron salts into the tissues during mummification. The femurs, tibias, and fibulas are intact without fractures or dislocations [FIGURE 16].



[FIGURE 16]: CT scan shows good preservation of the soft tissue and bones of the legs of Lady Amanit
© Photo taken by Ibrahim Badr

CT scan of the lower legs and feet showed that soft tissue was in a good state and bony preservation. There is loss of four toes on the left foot also seen on the visual examination. The right hand is visible on this image as the right arm is resting between the legs due to fracture at the level of the mid humerus [FIGURE 17].



[FIGURE 17]: The lower legs and feet are in a good state of preservation. There is loss of four toes on the left foot of the mummy. The right hand rests between the lower legs due to a fracture of the humerus and slippage of the right arm and hand © Photo taken by Ibrahim Badr

IV. DISCUSSION

1. This examination showed complete separation between the head and body of the mummy, indicating that caution should be taken during any restoration work on the necklace that covers the neck area overlying the area of separation.
2. This research conducted a study on the mummy «Amanit» from the Middle Kingdom period using both visual examination and CT scans. The external appearance of the mummy was studied using conventional visual examination, which was then compared to the internal examination performed using CT scans.
3. The CT scans provided detailed information of the internal structures of the mummy. The examination confirmed that the embalming process did not extract the brain from the cranial cavity, as some brain remnants were still present. The absence of any fractures in the skull and the intact ethmoid bones also support the finding that the mummy was not exacerbated. Soft tissue remnants of the heart, mediastinum and pleura were identified in the chest. In addition, soft tissue remnants of the bowel walls, rectum and bladder were seen in the abdominal cavity although no discrete organs could be identified. The lack of an abdominal wall incision supports the conclusion that the mummy did not undergo evisceration.

V. CONCLUSION

Since its inception in 1895, radiographic technology has been a significant contributor to the study of mummies. Radiographic examination as a non-destructive technique is a crucial procedure in any multidisciplinary study of mummified remains. It is now widely accepted that the examination and documentation of Egyptian mummies must follow advanced scientific methods to provide an accurate description of both internal and external conditions, including any damage that may affect preservation. The use of CT scans has become an essential and indispensable procedure for all mummies before any restoration or preservation work is undertaken. The CT scan contributes to creating complete documentation and recording of the internal structure of the mummy, which makes it easier for researchers and scholars to develop plans for preserving the mummy from various forms of deterioration.

Despite the available information on mummification techniques, some aspects of the process remain unclear. Relying solely on ancient classical writings to describe the embalming techniques used by ancient Egyptians is no longer considered scientifically acceptable.

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BIBLIOGRAPHY

- ALLAM, A.H., THOMPSON, R.C., WANN, L.S., MIYAMOTO, M.I. & THOMAS, G.S.: «Computed Tomographic Assessment of Atherosclerosis in Ancient Egyptian Mummies», *JAMA* 302/19, 2009, 2091-2094.
- ALLAM, H. et Al « Atherosclerosis Across 4000 Years of Human History: the Horus Study of Four Ancient Populations », *lancet* 6/381, 2013, 1211-1222.
- ALLAM, H., et Al.: «Atherosclerosis in Ancient Egyptian Mummies: The Horus Study», *JACC: Cardiovascular Imaging* 4/4, 2011, 315-327.
- AUFDERHEIDE, A.C.: *The Scientific Study of Mummies*, Cambridge (Cambridge University Press) 2003.
- BIERBRIER, M.L (ed.): *Who Was Who in Egyptology*, London (Egypt Exploration Society) 2012.
- BRIER, B. & WADE, R.S.: «The Use of Natron in Human Mummification: A Modern Experiment», *ZÄS* 124, 1997,89-100.
- CRAMER, L., BRIX, A., MATIN, E., RÜHLI, F. & HUSSEIN, K.: «Computed Tomography–Detected Paleopathologies in Ancient Egyptian Mummies», *Current Problems in Diagnostic Radiology* 47/4, 2018, 225-232.
- DARESSY, G.: «Les Rois Mentouhotep», *Sphinx* 17, 1913, 97-109.
- DARESSY, G.: «Notes et remarques». Recueil de travaux relatifs à la philologie et à l'archéologie égyptiennes et assyriennes 14, 1893, 166-170.
- DAVID, A.R. «Mummification», In P.T. NICHOLSON & I. SHAW (eds.), *Ancient Egyptian Materials and Technology*, Cambridge (Cambridge University Press) 2000, 372-389.
- DAVID, A.R.: *Mummification*. In K.A.BARD (ed.), *Encyclopedia of The Archaeology of Ancient Egypt*, London (Routledge) 1999, 543-546.
- DAVID, R.: *Egyptian Mummies and Modern Science*, London (Cambridge University Press) 2009.
- DAWSON, W.R.: «Making a Mummy», *JEA* 13, 1927a, 40-49.
- DAWSON, W.R.: *Magician and Leech: A Study in the Beginnings of Medicine with Special Reference to Ancient Egypt*, London (Methuen & Co) 1929.
- DAWSON, W.R.: *Magician and Leech: A Study in the Beginnings of Medicine with Special Reference to Ancient Egypt*, London (Methuen & Co) 1929.
- DERRY, D.E.: «Mummification. II-Methods Practiced at Different Periods». *ASAE* 41, 1942,240-265.
- ELADANY, A.: «A Study of a Selected Group of Third Intermediate Period Mummies in the British Museum», PhD Thesis, Faculty of Life Sciences/ University of Manchester, London, 2012.
- GHALIOUNGUI, P.: *Magic and Medical Science in Ancient Egypt*, London (Hodder & Stoughton) 1963.
- GOYON, J.C & JOSSET, P.: *Un Corps pour l'Eternite: Autopsie d'une Momie*, Paris (Editions le Leopard d'Or) 1988.
- GRAJETZKI, W.: *Burial Customs in Ancient Egypt: Life in Death for Rich and Poor*, London (Duckworth & Co Ltd) 2003, 231-236.
- HAWASS, Z., SALEEM, S.: *Scanning the Pharaohs: CT Imaging of the New Kingdom Royal Mummies*, (The American University in Cairo Press) 2016.
- IKRAM, S. & DODSON, A.: *The Mummy in Ancient Egypt: Equipping the Dead for Eternity*, London (Thames and Hudson Ltd) 1998.
- IKRAM, S., et Al.: «CT Imaging of Egyptian Mummies: a Review of Current Research», *Egyptian Journal of Radiology and Nuclear Medicine* 43/1, 2012, 55-61.
- KAMAL, H.: *Dictionary of Pharaonic Medicine*, Cairo (National Publication House) 1967.
- KEIMER, L.: *Remarques sur le tatouage dan l'Égypte Ancienne*, Mémoires de l'Institut d'Égypte LIII, 1948.
- LEEK, F.F.: «The Problem of Brain Removal during Embalming by the Ancient Egyptians», *JEA* 55, 1969, 112-116.
- LUCAS, A.: «Cedar"-Tree Products Employed in Mummification», *JEA* 17, 1931, 13-21.
- MÜNNEMANN, K., et Al.: «Noninvasive ¹H and ²³Na Nuclear Magnetic Resonance Imaging of Ancient Egyptian Human Mummified Tissue», *Magnetic Resonance Imaging* 25/9, 2007, 1341-1345.
- MURPHY, W., et Al.: « The Iceman: Discovery and Imaging. », *Radiology* 226/3, 2003, 614-629.
- RAVEN, M.: «Wax in Egyptian Magic and Symbolism», *Orientalia*, Nova Series (OMRO) 64, 1983, 7- 47.
- ROHRIG, C.: «Two Tattooed Women from Thebes», in OPPENHEIM, A. & G. GOELET (eds.), *The Art and Culture of Ancient Egypt: Studies in Honor of Dorothea Arnold*, BES 19, 2015, 527-536.

- RÜHLI, F.J., et Al.: «Current and Future Perspectives on the Imaging of Mummified Remains: a Survey of Literature», *Forensic Science, Medicine, & Pathology* 12/3, 2016, 355-360.
- SALEEM, S. N., SEDDIK, S. & EL-HALWAGY, M.: «Scanning and Three-Dimensional-Printing Using Computed Tomography of the “Golden Boy” mummy», *Frontiers in Medicine* 9, 2023, 1-15.
- SALEEM, S.N., HAWASS, Z., *Scanning the Pharaohs: CT Imaging of the New Kingdom Royal Mummies*, Cairo (American University in Cairo Press) 2015.
- SEIPEL, W.: Research on Mummies in Egyptology. An overview, in K. SPINDLER, H. WILFING, E. RASTBICHLER-ZISSERNIG, D. ZUR NEDDEN & H. NORTHDURFTER (eds.), *Human Mummies, A Global Survey of their Status and the Techniques of Conservation*, Vienna (Springer-Verlag) 1996, 41-45.
- SÉLINCOURT, A.D.: *Herodotus, the Histories*, Revised Edition, London (Penguin Books Ltd) 2003.
- TACONIS, W.K.: *Mummification in Ancient Egypt with a History of the Investigation of Egyptian Mummies*, in M.J. RAVEN & W.K. TACONISED (ed.), *Egyptian Mummies, Radiological Atlas of the Collections in the National Museum of Antiquities in Leiden* (Papers on Archaeology of the Leiden Museum of Antiquities 1) 2005, 35-51.
- TAYLOR, J.H.: *Death and Afterlife in Ancient Egypt*, London (The British Museum Press) 2001a.
- WINLOCK, H.E.: *The Rise and Fall of the Middle Kingdom at Thebes*, New York (Macmillan) 1947.
- ZINK, A.R., et Al.: «The Use of Computed Tomography in Anthropology», *American Journal of Physical Anthropology* 134, 2007, 243-244.