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Study of skin of an Egyptian mummy using a scanning electron microscope

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Abstract: The first study of modified human remains using an electron microscope was carried out at the end of the 1950 and in 1979 the first result of the study involving a scanning electron microscope (SEM) was published for the first time. The study was mainly focused on the structure of tissues and cells. With the help of this technique cell and tissue elements, viruses and bacterial endospores as well as the structure of epithelium and the collagen contents of dermis were identified and described. In the above-mentioned case the object of the study using a SEM was a free part of the right hand (forearm with the dorsal and palmar parts of hand) of unknown origin, with signs of mummification revealed during microscopic analysis. Our study was aimed at finding the answer to the question if the mummification of the studied limb was natural or intentional, and if the study using a SEM could link the anonymous remains with ancient Egypt.

Key words: mummification, SEM, interdisciplinary research

Introduction

Import of Egyptian mummies to Europe started as early as the Middle Ages when the mummy powder obtained from them found its use in medicine as a desired component of medicaments, whilst during the Renaissance period it was used for making paint of that time (Woodcock 1996).

After Napoleon's expedition to Egypt in 1978, a peculiar fashion for everything Egyptian including, of course, mummies dominated Europe. A massive influx of mummies to Europe dates back to the 19th century when mummies were

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treated as souvenirs from exotic trips to Egypt. The mummy bought by baron Anzelm von Rotschild in 1861 is an example of such an exotic souvenir. The baron bought the mummy as a gift for his fiancée. However, she didn't like the gift and the mummy, after many adventures, is now exhibited at the City Museum of Raciborz. The mummy was examined by Karl Lepsius, among others, and in the 20th century – by Niwinski. The affluence of a "tourist's" wallet was practically the only factor that influenced the decision whether to buy a whole mummy or just a fragment of it. Of particular interest were mummified heads which, placed under glass domes, served as salon decorations (Sefcakova 2005).

In April 1923, after the death of lord Carnarvon, one of the discoverers of Pharaoh Tutankhamun's tomb, and following the hysteria connected with the alleged "curse" unleashed by the press of that time, museums were flooded with parcels containing Egyptian relics including mummy fragments. According to the senders, the objects, not always being authentic, were burdened with a curse. Collections of such fragments are nowadays in the possession of the British Museum and the Czartoryski Museum in Cracow among others.

We will probably never find out how and when the forearm arrived in Poland. There is no detailed information about Egyptian relics kept in Polish museums and in private hands before World War II. It could have taken place before the year 1939 or, at the latest, shortly after the war ended. It is possible that one of the repatriates returning to Poland after the war brought such an exotic souvenir with him.

One of the earliest microscopic studies was the mummy skin analysis carried out in the 1950s (Leeson 1959). By the end of the 1970s, the first work was done using the SEM electron microscope. The study itself was the structure of the common and selected tissue (Hino 1982). The mention in this place is the use of new techniques in the identification of mummies also has Polish anthropology project: Results of Interdisciplinary Examination of the Egyptian Mummy of Aset-iri-khet-es from the Archeological Museum in Cracow (Kaczmarek 2001).

The purpose of the study was to determine whether the mummification of the limb occurred either through natural processes or through intentional intervention.

Material and method

In 2008 a mummified human forearm was handed over by the police to the Institute of Forensic Medicine at Warsaw Medical University. The man, who the forearm had been confiscated from, explained it was a fragment of an Egyptian mummy. The forearm was unwrapped from the original bandages which could have proved its Egyptian origin (Fig. 1).

The preserved fragment, in spite of slight build, must have belonged to an adult person (Winder et al. 2006). Examination and microscopic analysis did not make it possible to state unambiguously if the remains were part of an Egyptian mummy, though their ancient origin could not be excluded (Młodziejowski and Dąbkowska 2008).

Another examination was carried out in 2013 in the presence of an Egyptologist specializing in mummy studies and paleopathology. A stereo microscope was used for the examination.

The probability of Egyptian origin of the remains was proved. The skin cov-

Fig. 1. The forearm during examination. The state in 2008

ering the forearm was of homogenous ivory colour, with slight secondary discolouratins, thin, dry, but supple and elastic at the same time. Lack of signs of scabbing could indicate the effect of an agent, perhaps a chemical one, during the mummification process.

In order to perform microscopic analysis a spot for taking material was selected.

A skin sample of 3 cm × 2 cm was taken from the forearm. The skin strip was sputtered with gold (Au) in a Q150R S sputter coater, in a vacuum.

The sample prepared in that way was placed in a Zeiss EVO-10 scanning electron microscope. Although using a SEM is clinically justified, it is still rarely applied in anthropology (Papageorgopoulou et al. 2010). The scanning electron microscope (SEM) is a device built on the principle of an optical microscope, where a stream of light has been replaced by a stream of electrons. The obtained images are characterized by high depth of sharpness incomparable to the sharpness obtained with a traditional microscope. The only limitations are: electrical conduction of a sample and necessity to perform the examination in vacuum conditions (Fig. 2).

The examination also revealed a skin change with a diameter of approx. 1mm at the nail bed of the fourth finger (Liddel 2004).

The samples taken from the area of the skin change were divided into fragments. Sodium cacodylate buffered glutaraldehyde was applied for 10 days, which made it possible to remove the materials used for embalming, and which proved that such a treatment had taken place.

Fig. 2. Traces of insect feeding

The results of histopathological analysis and CT-scanning of the forearm will be published later.

Results

The routine examination concerned the macroscopic structure and the state of limb preservation. It also made it possible to conclude that the limb had been mechanically torn off from the shoulder at the elbow joint. This was indicated by the irregular ends of the tendon remnants, as well as the remnants of flexor muscles, finger extensors and elbow joint. The hypothesis as to the modern origin of the remains was turned down at the beginning. The skin on the limb, in spite of dehydration, is quite well-preserved. The dehydration, as a result of lyophilisation, led to the hardening of epidermis and collagen fibres in the dermis. Collagen fibres in the dermis form thick bundles and are arranged in a characteristic way (Perin et al. 1994). It is known now that both elastic and collagen fibres are identifiable. Their arrangement in the tissues of the mummified corpse coincides with the arrangement observed in modern human tissues.

The revealed skin change can be a wart *(verrucae vulgares)*. Cases of similar skin changes are known from the research on Egyptian mummies. J.Verbov (1983) has described signs of pox, blackheads, ulcers, inflammatory tumours and pim-

Fig. 3. Sample after covering gold

ples observed on mummies, cases of callused skin formed under the influence of sunbeams have also been stated (David 1986; Byung 2006). Similar changes have also been described by Leslie (2006).

The applied macroscopic technique revealed traces of insect feeding on the inner side of the palmar part (Fig. 2).

The images obtained in the electron microscope showed distinct imprints of the weft and warp lines of bandages. Each of the samples from different areas of the skin contains prominent impressions of the fabric weave, which may suggest the Egyptian origin of the mummified limb. The fiber fleece indicates the use of flax. It has been observed that the edges of the fabric, which was used to bandage, are irregular, which may indicate a possible mummification before the Ptolemaic period (Fig. 4, A, A1, B, B1, C).

The imprints (weaving pattern) were explained to have come from the rolls of the fabric used in the final stage of the mummification process. A similar fabric structure of ancient Egyptian bandages was revealed during the research carried out as part of Manchester Museum Mummy Project (David 1979).

Moreover, in the top left-hand corner of the sample a structure formed by two lines touching each other at a right angle and creating a stair-like imprint was revealed. It cannot be excluded that this is a fragmentary imprint of an amulet, jewellery or another layer of bandages.

During the examination performed in 2008 the following inscription S 733 hp 19581 written in black ink was discovered on the anterior surface of the radial bone head. (Fig. 5)

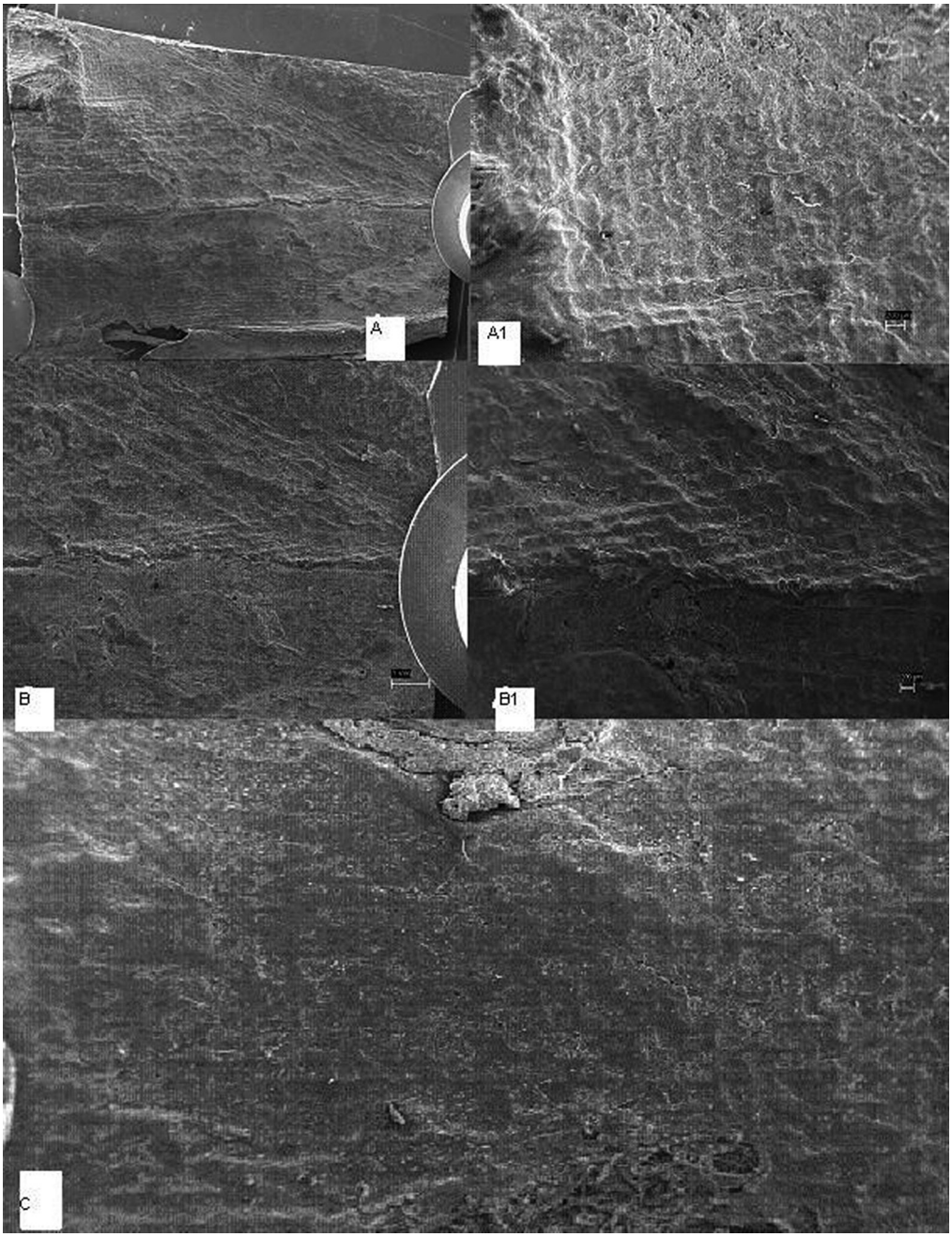

Fig. 4. Photo A – sample view. Photo A1 – enlarged image of the "stair". Size – 2 μm.Photo B – sample view. Photo B1 – enlarged fragment. Size - 200 μm. Photo C. Sample photographed in the light visible with the help of a miniature digital microscope, before sputtering with gold. Size - 300 μm

Fig. 5. Inscription on the radial bone

This inscription might have been an inventory number of a museum or private collection, though the second option seems less probable. At present it appears impossible to find out what collection the forearm comes from.

Discussion

Different factors have influenced the preservation state of the find. The first of them is the mummification process itself.

In the case of Egyptian mummies the basic chemical agent affecting the tissues was natron, a mixture of sodium compounds, which can be found in a natural state in Egypt in Wadi Natrun. As it is known, it is a substance with strong hygroscopic properties that was used by ancient Egyptians for drying bodies of the dead (Ikram and Dodson 2009).

In 1997 egyptologist B. Brier and pathologist S. Wade performed an experimental mummification of human corpse using old Egyptian materials and techniques. During the experiment, after emptying the corpse from internal organs, the body, in accordance with the Egyptian canon, was placed in natron for 35 days. Brier and Wade claim that after removing the natron the tissues were dry but elastic at the same time (Brier and Wade 1997).

Our own study has also confirmed this fact.

Insect necrophages as well as flies, at different stages of development, are a frequent find in the case of Egyptian mummies (Panagiotakopulu 2009). Their presence has been observed be-

tween bandages, inside mummies, e.g. in the abdominal cavity or sunk in the resin covering the mummies (Huchet 2010). Part of damages to mummies is also caused due to dreadful exposition and storage conditions and is the result of the activity of insects from the *Dermestidae* family. In the case discussed, due to the lack of adult insects, larvae or pupae, it is not possible to define a species responsible for causing damages (Abdel-Maksoud at al 2011).

Every Egyptian mummy was wrapped in many layers of bandages that were saturated during application with hot resin which is a liquid mixture of cedar oil, myrrh and other aromatic vegetable substances. When becoming cold, the resin together with the bandages formed a hard coating which additionally protected a mummy from damage, whilst when drying, the bandages shrank and left imprints of fabric texture on the skin. Finds of bandage imprints on the skin of Egyptian mummies are frequent. They are present on the mummy of Ramses V and many others (Cockburn 1980). On the forehead, slightly above the superciliary arch, as well as on the right temporal bone a distinct line is visible. This is an imprint of a bandage or a linen cap in which the pharaoh was dressed during mummification (Nameckova 1977).

On the studied forearm there is a visible imprint of fabric texture, which can be seen at microscopic examination. This proves the performance of intentional mummification in the way typical of ancient Egypt.

Studies of mummy skin using an electron microscope have already been carried out in order to define the degree of skin degradation caused by mummification processes. It is known today that the skin of natural mummies looks different from the skin of mummies that have been preserved intentionally (Montes et al. 1985). Stani, having performed comparative and histological analysis as well as analysis applying the method of Fourier transform infrared spectroscopy, has proved that the skin of intentional mummies is better-preserved than that of natural mummies (Stani et al. 2014).

The study of mummified skin carried out with the use of a scanning electron microscope (SEM) appears to be the first study of its kind in Poland. The imprints of ancient bandages revealed during the research made it possible to unambiguously confirm the origin of the forearm from an ancient Egyptian mummy. The suggested method can successfully be applied for both archeological and forensic medicine studies (Cersoy et al. 2012, Cotte et al. 2004).

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Authors' contributions

HMP was the main author and primary researcher; HP merit care; MN and PW made figures; ST, AD, MF, ER, DH were collaborative researchers AP and DH collected the literature.

Conflict of interest

The authors declare that there is no conflict of interests.

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