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Imaging Fingerprints of an Ancient Egyptian Mummy by Propagation-Based Phase-Contrast X-Ray Tomography.

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Mapping of fingerprints has long been the method of choice for identification of individuals in forensic science, since the friction ridges of the skin of the fingers provide a unique pattern that can be replicated. However, in the case of old or mummified cadavers, post-mortem changes to the skin make imaging of the ridges difficult. To enable replication of the prints by classical fingerprinting methods, such as photography, inked impression or dusting tape, the fingers must first be rehydrated. This requires, e.g, immersion in boiling water, or bathing the sample in reagent solutions for several days [1,2]. Here, we suggest fingerprinting by phase-contrast x-ray tomography, a non-intrusive high-resolution imaging method with enough soft-tissue contrast to resolve both the friction ridges and the microanatomy of the mummified soft tissue [3]. The method is demonstrated on a mummified hand from ancient Egypt.

The phase-contrast tomography arrangement consists of a liquid-metal-jet x-ray source [4] (MetalJet D2, Excillum AB), a rotation stage (URS50BCC, Newport) for the sample, and a high-resolution detector (Dual X-Ray FDS Large-Area CCD, Photonic Science) with a 100 µm structured CsI scintillator. The detector is placed at a distance from the sample, allowing the x-ray beam to propagate and interfere. This provides a translation of the phase variations induced by the sample to intensity variations that can be measured by the detector. The recorded image, which is a combination of phase and absorption contrast, is flat-field corrected and phase retrieved before further processing [5].

A detached mummified human hand from ancient Egypt was imaged. The skin, fingernails and linen wrappings of the hand are well preserved. The hand was placed upright in a plastic cylinder and padded with plastic foam to avoid movements during rotation. Distances between source and sample, and between sample and detector were 98 cm and 22 cm, respectively, giving an object-plane voxel size of 14 × 14 × 14 µm. The x-ray source was operated at 100 W and with an electron beam focus of 40 × 10 µm on the liquid-metal-jet anode. With an acceleration voltage of 80 kV, the mean x-ray photon energy was 17 keV. The exposure time per projection was 10 s, and 900 projections were acquired over 180°. Tomographic reconstruction of the phase retrieved images was performed in Octopus Reconstruction. Further image processing and visualization were done in ImageJ and Amira.

The fifth finger of the mummified hand shows the best preservation. Here, the wrapping is intact on the palmar side of the finger, and hence the skin has been protected from outer damage. Figure 1 shows a volume reconstruction of the distal phalange of the finger. The wrapping has been virtually removed by manual segmentation to show the surface of the skin, which is wrinkled as a result of the desiccation. Some residues of the embalming process can be seen, attached to the epidermis (A). Where the skin is laid bare, the ridges constituting the fingerprint can clearly be seen (B).

An axial slice of the finger tip is shown in Fig. 2. We identify the bone (A) and finger nail (B). Dermal ridges are visible (C) where the skin is free from dirt and embalming residues (D). The layers of linen (E) on the palmar side have helped preserving the skin of the finger for thousands of years.

This study has shown that fingerprints of an old and dehydrated human hand can be imaged using phase-contrast tomography. Here, tomography is performed on a mummy from ancient Egypt, but there is no restriction to artificially mummified specimens as long as the skin is still present. Hence, this method has potential impact not only for the study of mummies but also for forensic science, as a non-destructive alternative to the chemical fingerprinting methods used today. Future challenges include refining segmentation methods to separate the residues and dirt from the skin, as well as virtually flattening the wrinkles to enable extraction of the fine friction ridges and subsequently get a 2D print, similar to that of the dusting tape or inked impression methods [6].

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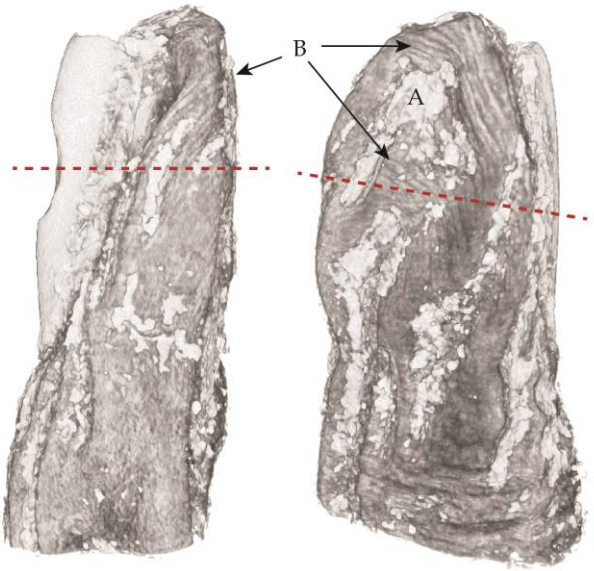

Figure 1. Volume rendering of the fifth fingertip of the mummified hand, with the wrapping virtually removed. Ulnar (left) and palmar (right) views. Residues from embalming (A) cover parts of the surface, but where the skin is bare the fingerprints can be clearly seen (B).

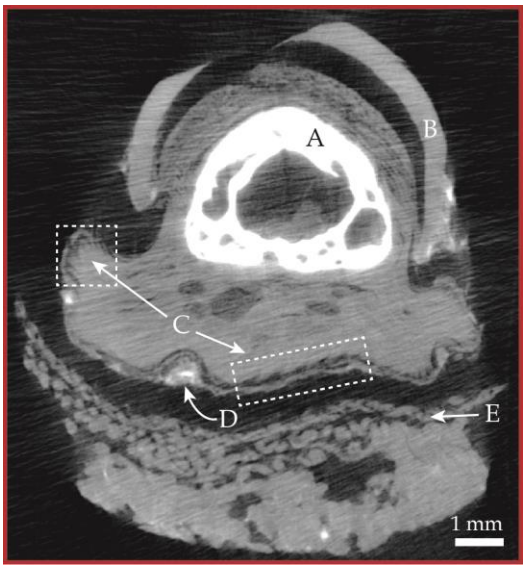

Figure 2. Axial slice at the dashed line in Fig. 1. We identify the bone (A), nail (B) and the ridges of the skin (C). Some residues from the embalming process can be seen (D). The palmar side of the finger is enclosed in linen (E).

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