Department of medical history

Ancient Egyptian prosthesis of the big toe

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Introduction

Up to now, there has been mainly indirect evidence from written sources that the ancient Egyptians practised surgery, and none that their medical treatments also included therapeutic replacement of amputated limbs with prostheses. Medical papyri describe treatment of traumatic lesions, but fail specifically to mention the use of surgery. However, findings such as an externally treated fracture of the forearm with wooden splints[1] and a 19th dynasty bone (circa 2100 BC) from a presumably post-traumatic amputation of the forearm with subsequent distal synostotic fusion of radius and ulna,[2] do imply that surgical treatment took place in ancient Egypt. Furthermore, a new report[3] of a skull with a large post-traumatic osseous defect and missing fracture fragment, but intact internal (dura mater) and external (skin) soft tissue layers, argues in favour of some kind of surgical removal of that fragment. During our palaeopathological survey of human remains in the necropolis of Thebes-West, the large cemetery of the capital of ancient Egypt during the New Kingdom and subsequent periods (about 1550–700 BC), we discovered an Egyptian mummy with an intravital amputation of the big toe.

The Thebes-West tomb

During an excavation campaign at the necropolis of Thebes-West (Sheik-Abd-el-Gurna), by the German Institute of Archaeology, Cairo, and the Supreme Council of Antiquities in Egypt, we investigated the human remains of burial chamber TT-95, one of the tombs of the nobles. This tomb was built during the 18th dynasty (circa 1550–1300 BC) by a high royal official and, according to archaeological findings, was originally used by members of his family. However, in subsequent periods, the tomb complex was reused as a burial place by others. This practice holds particularly true for an additional burial chamber located at the end of a shaft originating from the transverse hall of the burial chapel. The room was built in the third intermediate period (circa 1065–650 BC) and the presence of cartonnage and coffin fragments (yellow type coffins), and funerary pottery, typical of the 21st and 22nd dynasty (circa 1065–740 BC),[4] suggests that it was used during that period. Lack of funerary material from later periods excludes its subsequent use. Therefore, the remains of several individuals found in the chamber were archaeologically dated to the early third intermediate period (21st/22nd dynasty).

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The mummy

In the additional chamber, we found the fragmented, but otherwise well-preserved mummy of a woman (figure 1). The corpse had been broken into several parts, so that the skull, abdominothoracic torso, right thigh, both shins, and both arms were separate, but could easily be reassembled. All parts of the mummy were extensively wrapped in linen bindings and only the embalmed left thigh and both hands were missing. The torso, probably because of grave robberies, was ventrally disrupted and fragmented. Most of the internal organs were missing and whether their absence was due to the embalming process or to disruption during plundering is unclear. However, a 12 cm segment of aorta, found immediately above the vertebral column, could be anatomically identified.

Anthropological investigation of cranial sutures of the skull and symphyseal pubis morphology indicated that the mummy was a 50–60-year-old woman.[5] Age of the mummy at death was confirmed by histological examination of incremental lines of the dental cement of a tooth,[6] which showed her to be 50–55 years old. The woman was about 169 cm tall, calculated from the length of her long bones.[7]

A subsequent extensive palaeopathological examination showed that the big toe of the right foot had been amputated. The toe had been removed during her lifetime, because the amputation site was covered by an intact layer of soft tissue, including skin (figure 2, A). The missing toe had been replaced by a wooden prosthesis (figure 2, B), painted dark brown and made up of three separate components. The main component consisted of a longitudinal wooden corpus (12×3·5×3·5 cm) and replaced the toe. This corpus was attached to two small wooden plates (together about 4×2·5×0·3 cm). These plates were fixed to each other by seven leather strings. All wooden parts were delicately manufactured and the major corpus of the prosthesis perfectly shaped like a big toe, even including the nail. A broad textile lace was fixed to the small plates and to the prosthetic corpus, which was tied around the forefoot (see figure 2, B), fixing the toe firmly in place. This construction provided sufficient stability to keep the prosthesis in the correct position, and allow the user to move without major restrictions. Careful inspection revealed clear marks of use on the sole of the prosthetic toe (figure 2, C).

Further examination of the forefoot by macroscopy, plain radiology, and computed tomograms (CT) showed that the first metatarsal bone was somewhat demineralised, and that extensive osteophytic osseous overgrowth of the amputation end had taken place (figure 2, D). By contrast, the other metatarsals, as well as the digits, were shaped and mineralised regularly, and did not show pathological features. However, CTs of the mummified soft tissues revealed small peripheral arterial cross-sections with irregular and focal calcifications of the small arterial walls, suggesting segmental or focal peripheral arteriosclerosis (figure 3, A). The aortic segment, found in the mummy's abdomen, revealed an

Figure 1: **A complete overview of the mummy after reconstruction**

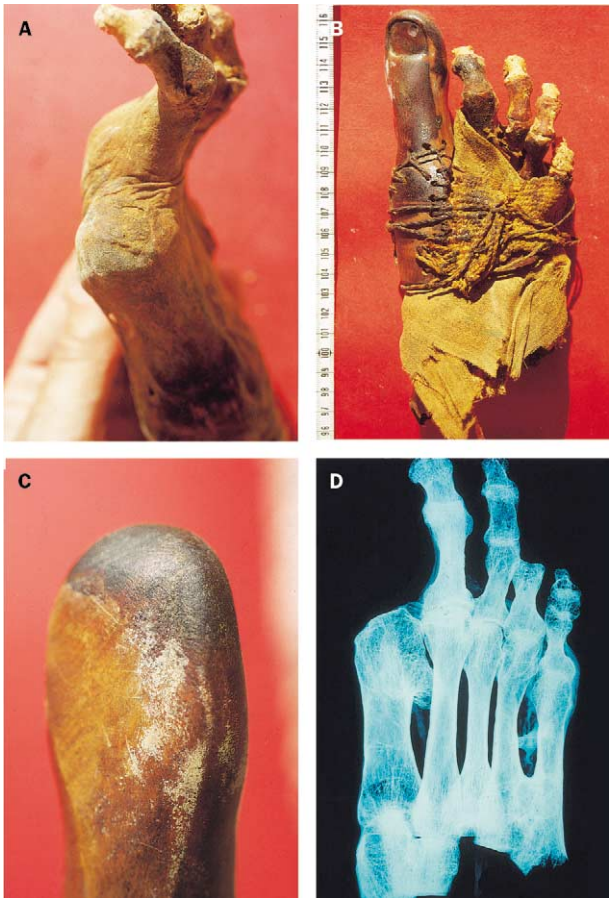

Figure 2: **Views of right foot and prosthesis**
A, well-healed amputation area covered by intact layer of skin. B, well-crafted wooden prosthesis, attached to the forefoot by a textile lace. C, basal surface of prosthesis showing abrasion of the wooden surface and several scratch marks indicating intravital use. D, radiograph showing bony overgrowth of the first metatarsal indicating longstanding intravital amputation of the big toe. Note the enhanced demineralisation of the first metatarsal.

irregular distension of the arterial walls and focal severe calcifications. This observation was confirmed by radiographs taken from an aortal segment (figure 3, B) and indicated severe calcifying arteriosclerosis of the aorta (macroangiopathy).

Further inspection of the mummy revealed, on several cross-sections through the bones, slight mineral deficiency (mild osteopenia) which was, however, restricted to the bones of both legs and did not obviously affect the trabecular structure of the vertebral bodies, the long bones of the arms, or the ribs. This pattern of osteopenia excludes age-related or hormonally-induced osteoporosis such as is commonly seen in present-day people, and suggests that a general disuse of the legs might have been the underlying cause. Since both legs were affected, an isolated disease of the side with the prosthesis is unlikely.

Finally, we noticed severe abrasion of all teeth, presumably caused by dental wear. Such wear is a feature generally seen in ancient Egyptian populations and is assumed to result from sand and debris from stone mills found in food, particularly in bread.[8] In addition, six teeth had carious processes and one of these showed an apical inflammatory process, as is frequently seen in these people.[8] Three teeth had been lost during life.

Discussion

We describe possibly the oldest known intravital limb prosthesis. Up to now, several investigators have reported prosthetic replacements of limbs in ancient Egyptian

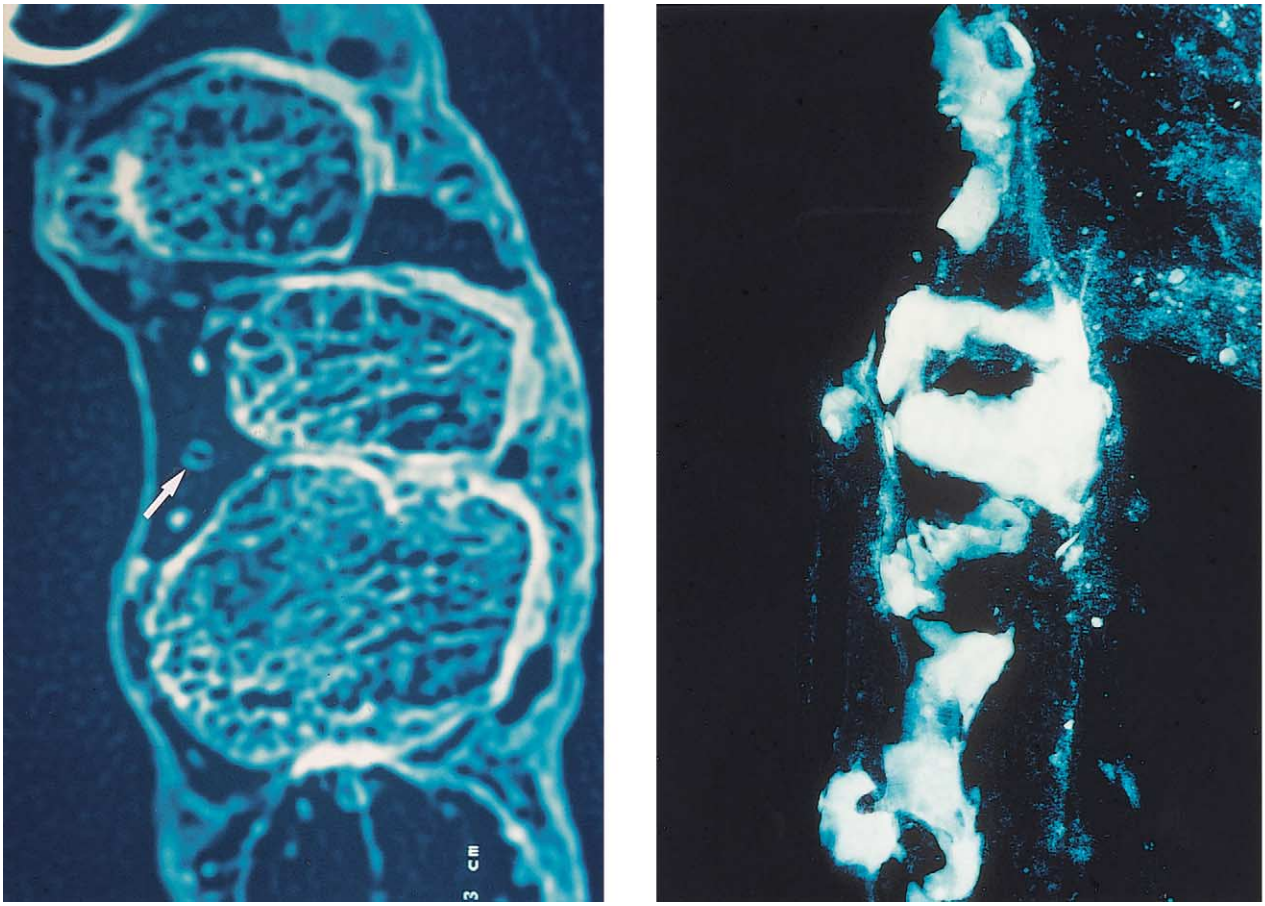

Figure 3: **CT scans of forefoot proximal to the amputation site (A) and radiological examination of a segment of abdominal aorta (B)**
Of note are small arterial vessels (arrow) in (A) which show calcification of the vessel wall, and severe calcifications indicating major arteriosclerosis in (B).

mummies. However, their findings suggest that the replacements were made to prepare the mummy for its afterlife. For example, a previously found forearm prosthesis of an elderly man from the Ptolemeic period (332–30 BC) revealed attempts by embalmers to complete the mummy for the afterlife.[9] Gray[10] has detailed further similar prosthetic replacements of limbs. Similarly, a wooden prosthesis of the nose of a male mummy from the Roman period (about 1st century AD)[11] is believed to have been added after death to restore the mummy's external integrity, and not for aesthetic reasons during life, since it was attached to the mummy by a delicate rope turned around the skull and fixed tightly to the mandibula.[11] There is also a debate about two dental prostheses found several years ago near Cairo (Saqqara, 4th dynasty, and El-Qatta, Ptolemeic period).[12,13] The teeth were initially interpreted as intravitally used dental prostheses, however, the absence of dental wear and dental calculus on the teeth argues against use in life.[14]

Recently, CT analysis of a female mummy from the Albany Institute of History and Art (Albany, NY) provided evidence that the right big toe of this corpse had been replaced by a prosthesis.[15] However, only CT investigation of this object exists, and whether the prosthesis had been used during life or if it had been added after death remains unclear. Furthermore, both the source and function of this prosthesis are uncertain, because measurement of the radiological density suggests that the toe consisted of some form of high-density ceramic; a material unknown in ancient Egypt. Notably, the mummy comes from the Theban necropolis and dates back to the 21st dynasty, thereby closely resembling the spatial and temporal origin of our case.

A further example of an ancient Egyptian toe prosthesis is housed in the Egyptian department of the British Museum. This prosthesis, made from a certain kind of cartonnage, had been brought to the British Museum in 1881 and also originated from Thebes. Although no information is available on the individual who used the toe, distinct signs of wear and subsequent refurbishment suggest that this prosthesis was also used during life.[16]

These observations provide compelling evidence that the surgical expertise to carry out toe, and possibly other amputations, sometimes followed by prosthetic replacement, was present in Egypt during this period. The big toe usually bears about 40% of walking weight and its replacement is, therefore, of certain importance to the user's physical integrity. The loss of this digit results in a transfer of weight to the end of the first metatarsal, resulting in instability while standing and in limping when attempting to run. Use of a prosthesis would have solved these problems.

In addition to the amputation and prosthetic replacement of the big toe, we present evidence that the underlying pathological condition could have arisen from clinically significant systemic arteriosclerosis, since radiographs and CT scans show severe arteriosclerotic macroangiopathy of the aorta with extensive calcifications and arteriosclerotic microangiopathy of small arterial vessels of the affected foot. We cannot speculate on whether this amputation was done by surgery or if it took place naturally. Traumatic loss of the toe, however, is unlikely. Unfortunately, we were not able to do further CT scans on other body regions of the mummy.

The presence of arteriosclerosis in ancient Egyptian mummies has been repeatedly documented.[17,19] In our case, the arteriosclerotic lesions affected not only the major arterial vessels, but also small peripheral vessels, suggesting a metabolic disorder such as diabetic angiopathy. Although this diagnosis cannot be substantiated, and there are of course several other major contributing factors possibly involved, we suggest that ischaemic gangrene could have led to amputation of the big toe.

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