A possible Madura foot from medieval Estremoz, Southern Portugal

Ana Curto[a,c,*], Teresa Fernandes[b,c]

[a] Skeletal Biology Research Centre (SBRC), School of Anthropology and Conservation, The University of Kent, Canterbury CT2 7NR, UK
[b] Department of Biology, School of Science and Technology, University of Évora, 7002-554 Évora, Portugal [c] CIAS (Research Centre for Anthropology and Health), Department of Life Sciences, University of Coimbra, 3000-456 Coimbra, Portugal

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abstract

Madurmycosis, commonly called Madura foot, is na infectious pathology caused by fungi or bacteria, and it is native of the tropical, subtropical and equatorial areas. This paper presents a well preserved male skeleton, between 23 and 57 years old from a medieval necropolis (13th–15th centuries) in Estremoz, Portugal. The left foot of this individual showed marked alterations on the morphology of the calcaneus and cuboid that are ankylosed, which led to arthrosis of the calcaneous and talus. The five metatarsals have bone destruction and irregular subperiosteal new bone formation with multiple lytic foci and progressive osteoporosis with very little reactive bone formation. After a careful differential diagnosis, taking into consideration various pathological conditions, it was concluded that this is a possible case of maduromycosis. This study suggests that in the past this pathology could have been present in Europe, particularly in the Mediterranean region, and especially when the climatic conditions were conducive. This could be one of the first cases of maduromycosis infection published in na archaeological context.

1. Introduction

Madurmycosis is a chronic, progressive and granulomatous inflammatory disease that may affect subcutaneous tissues and sometimes bones, but rarely viscera (Arenas and Lavalle, 2001; Fahal, 2011). This pathology is the consequence of traumatic inoculation of the skin by the causative pathogen, which can be actinomycetes (filamentous bacteria) or eumicycetes (true fungi) (Fahal, 2011). While fungal grains grow in drier areas, actinomycetes are more common in wet áreas (Dieng et al., 2003; Fahal, 2004). The actinomycetes expand faster, being more invasive and having more, smaller sinuses than eumycotic variants (Davies, 1958; Magana, 1984).

Madurmycosis has a long, painless and asymptomatic incubation period, which varies from several weeks to months or even years (Arenas and Lavalle, 2001; Magana, 1984). This pathology involves the subcutaneous tissues and probably originates with a traumatic inoculation of the pathogen that later spreads through the skin and deep structures, such as bone, resulting in destruction, deformity and loss of function (Arenas and Lavalle, 2001; Fahal, 2011). Difficulty in accurately identifying the limits and spread of the disease during surgery may lead to recurrence and amputation (El Bagi, 2003). Complications include secondary bacterial infections that can progress to bacteremia or septicaemia resulting in death (Venkatswami et al., 2012).

The common name for pedal maduromycosisis Madura foot, deriving from the city of Madurai, in India, where it was first medically reported in the middle of the 1800's (Bonifaz et al., 2014), although it seems to have been first described in the Indian Sanskrit text Atharva Veda (Hospenthal, 2009). Madura foot is native to the tropical, subtropical and equatorial areas between latitudes 30◦N and 15◦S in the commonly called "mycetoma belt" (Bakshi and Mathur, 2008), especially among barefoot populations (Tomczyk et al., 2014) and agricultural workers (Bonifaz et al., 2014). Environmental factors such as rainfall play an important role in the distribution of this disease, as well as the nature of the soil and presence of abundant, sharp, thorny vegetation (Mathur et al., 1979). These reasons, it is most common in the foot, although it can also occur in the thigh, knee and lower leg, the hand, forearm, arm, shoulder, back, abdominal wall and chest, as well as occasionally in the head or face (Arenas and Lavalle, 2001). This pathology is more common in males (Bakshi and Mathur, 2008; Bonifaz et al., 2014) due to activity but also to possible inhibition of the growth of some of these pathogens caused by progesterone (Hernández-Hernández et al., 1995; Hospenthal, 2009). The first three clinical cases reported for Europe came from Greece, Southern Italy and Sardinia (Plehn, 1928). In Portugal, two cases of maduromycosis caused by Nocardia asteroides were recorded in 1963 (Brandão and Figueiredo, 1963 in Cabrita, 1974) and 1970 (Nobre, 1970 in Cabrita, 1974), and one infection by Madurellamycetomi in 1971 (Cabrita and Figueiredo, 1971 in Cabrita, 1974). These three individuals had never been outsider Continental Portugal so they must have been infected in Europe, although it is not clear if the presence of these pathogens is related with peoples' movement to and from Africa, especially within the then Portuguese Overseas Provinces, such as Mozambique, Angola and Guinea. Recently more cases have been reported, especially among migrant populations due to increased mobility of people (El Muttardi et al., 2010; Buonfrate et al., 2014; Iniesta et al., 2015). One of these cases was reported in Portugal: a 43-year old female born in Cape Verde from whose infection molecular diagnosis revealed the presence of Madurellamycetomatis (Mestre et al., 2015). Recently a 46-year-old Portuguese male farmer with a swelling on his right foot, with eighty ears of evolution, was diagnosed as na actinomycetoma case (Ramos et al., 2013). This individual was infected in the Madeira Island, following a trauma on the instep, while working on the fields.

Mycotic disease is uncommon on paleopathology, in part due to the low skeletal involvement for this group of pathologies. Only a few cases of Madura foot have been described from the paleopathological record, and none of them from Europe.

In Mexico a case of Madura foot was reported in a male between 25 and 30 years old from the Tlatilco collection (1300–100 B.C.) with 459 skeletons (Mansilla-Lory and Conteras-López, 2009). There is also a case reported from the Byzantine period (A.D. 300–600) in Israel (Hershkovitz et al., 1992), but this was later diagnosed as an exemple of leprosy (Spigelman and Donoghue, 2001), as first suggested by Manchester (1993). This may, however, also represent Madura foot as well as leprosy (Spigelman and Donoghue, 2001).

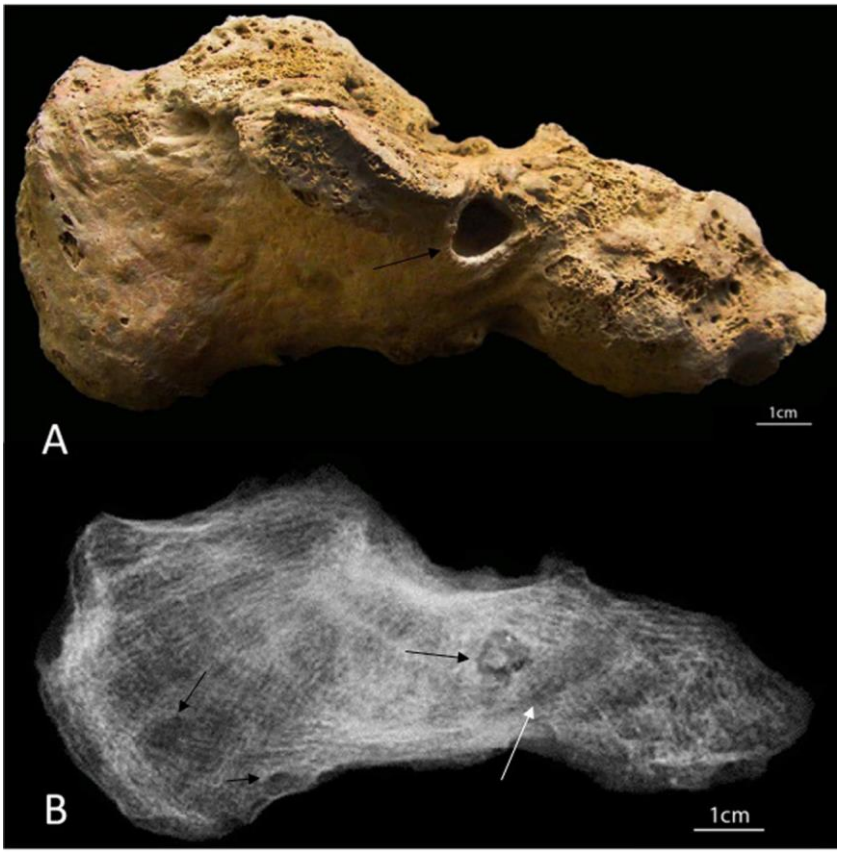

Fig. 1. Ankylosis of the left calcaneous and cuboid (3D imaging available at https://sketchfab.com/models/7338e70695b34439b8421d014b593610). (A) Photography showing external foci (blackarrow). (B) Radiograph showing multiple foci (black arrows) and the lines (white arrow) between the calcaneus and cuboid.

Fig. 2. Ankylosis of the left calcaneus and cuboid, as well as arthrosis at the talo-calcaneus articulation and the irregular subperiosteal new bone formations (circles) and lytic external foci (arrows) in the left metatarsals.

2. Materials and methods

The study subject was analysed following various methodologies. Sex was accessed based on pélvis features (Bruzek, 2002). Age at death was estimated from the degeneration of the pubic symphysis (Brooks and Suchey, 1990). Maximum length of the second right metatarsal was used to establish stature (Santos, 2002). The methodologies suggested that the skeleton analysed was a male, between 23 and 57 years old and approximately 159 cm in height. It was recovered from a necropolis in Estremoz, in southern Portugal. During excavation, 115 individuals were recovered, of which 72 were adults: 32 males, 22 females. It was not possible to estimate biological in na additional 18 skeletons due to poor preservation and incompleteness of the remains. In this cemetery all skeletons were in supine decubitus position and oriented from West to East, without archaeological artefacts, which is typical of Christian burials. Radiocarbon dating of two other individuals, indicated a time period between the 13th and the15th century (BP 680 to 530 and BP 670 to 530 for 2Sigma calibration, with 95% probability). This relatively large time frame makes more precise characterisation of the necropolis impossible since this was a period of significant historical and environmental upheaval in Portugal. Exhaustive macroscopic and radiographic observations (performed with a digital system Mammo Diagnost UC Philips, at 28 kV and 25 mA, coarse focus, using Kodak Min-R screen film) were performed on the skeleton in order to describe the lesions as well as to identify other anomalies helpful to the differential diagnosis. A 3D image of the left calcaneus and cuboid was created with the software Agisoft PhotoScan, using 360◦ photography.

3. Results and discussion

Most of the bones from skeleton RMPE-121 are well preserved, with the exception of the facial bones, forearm bones and right tibia and fibula. The left foot (Fig. 1) of this individual showed ankylosis of the calcaneus and cuboid indicating a reactive process that led to arthrosis of the calcaneus and talus.

The five metatarsals have antemortem bone destruction and irregular subperiosteal new bone formation (Fig. 2). The Radiograph (Fig. 1B) showed no signs of any fracture lines but, in at least four metatarsals (Fig. 3) and the calcaneus, multiple round lytic foci of similar size were observed (approximately 7.8 mm in diameter), and progressive osteoporosis with very little reactive bone formation. Since the right foot is fragmented, we may only observe that there are no lesions similar to those described for the left foot.

The left distal tíbia and fíbula also display periostitis, as well as ossification of the interosseous ligament and patellar ligament at the tibia. The right fibular interosseous ligament ossification is even more marked, but the right tibia is too fragmented for comparison. In contrast to the left foot, the right foot has no visible lesions; the rest of the skeleton does not show any sign of similar lesions or any other infectious pathology. There is also no asymmetry at the arms or femoral robustness that could be related to limited mobility. It would be expected that such a severe case would be incapacitating for the left lower limb, but this absence of asymmetry could be due to a rapid spread of the infection (Aufderheide and Rodríguez Martín, 1998; Ortner, 2003).

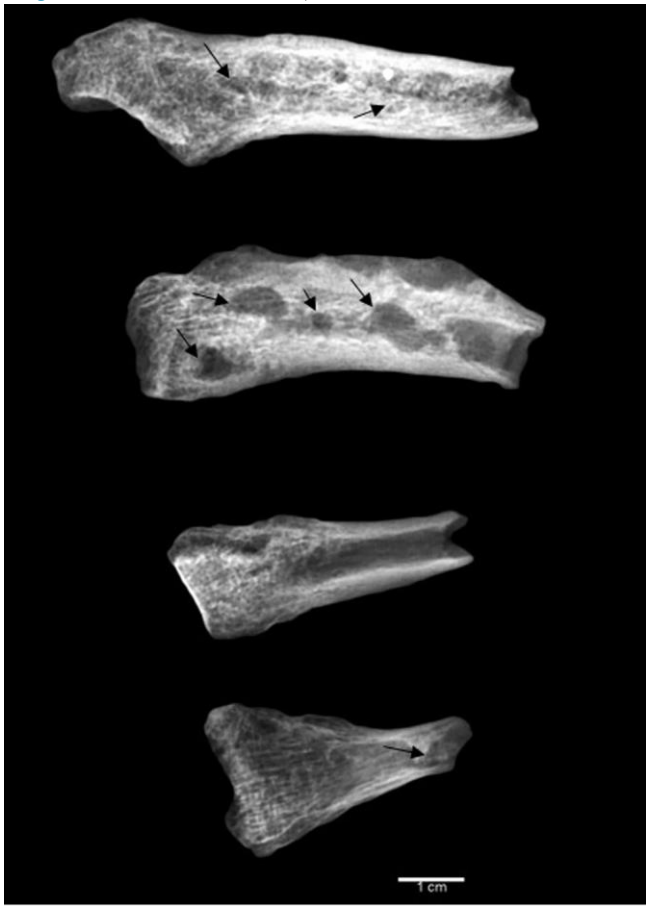

Fig. 3. Radiograph of lef t metatarsals showing multiple round lytic foci (arrows) of similar size.

3.1. Differential diagnosis:

3.1.1. Leprosy

Although the facial bones are poorly preserved, the nasal spine is intact. There is also no bone loss at the phalanges (including distal phalanges) of either hands or feet. This, alongside with the asymmetric distribution of the lesions, does not correspond to a classic pattern of leprosy infection (Aufderheide and Rodríguez-Martín, 1998; Ortner, 2003; Waldron, 2009).

3.1.2. Malignant tumours

Multiple myeloma is characterized by sharply localized lytic dissolution of bone without reactive new bone formation (Aufderheide and Rodríguez-Martín, 1998). The lesions observed here are not widely distributed, being only present in the left foot and not affecting the commonly anatomic regions such as mandible, acromion, glenoid and olecranon, scapula, clavicle, radius and ulna (Aufderheide and Rodríguez-Martín, 1998). Chondrosarcoma causes scalloping in the medulla similar to the ones observed here in the left foot. However, chondrosarcoma is more common in the pelvis, femur, tibia, ribs, sternum, scapula, spine and humerus medulla (Aufderheide and Rodríguez-Martín, 1998). Metastatic neoplasms can also cause similar lesions but are usually multiple and more frequente in the vertebrae, pelvis, skull, ribs and proximal fémur and humerus (Brothwell, 2008).

3.1.3. Congenital ankylosis

The ankylosis of the calcaneus and cuboid could be a congenital anomaly but the X-ray shows fine lines between the limits of the bones and the foci. These do not appear to be compatible with congenital tarsal blocks.

3.1.4. Tuberculosis of the ankle and subacute osteomyelitis

It may be impossible to achieve a differential diagnosis between these two conditions due to their similarities. Although these two pathologies are usually asymmetric and may cause a cavity with a central spongiosa sequestrum and perifocal osteosclerosis (Ortner, 2003), the similar size and number of foci are not expected in any of the infections above, as well as the little associated proliferative new bone formation. Fracture lines are not visible as well, although it does not make the occurrence of a traumatic lesion fallowed by infection impossible. For these reasons it does not seem probable that this case could result from one of these two infections although they cannot definitively be exclude.

3.1.5. Maduromycosis

A chronic disease that involves mainly the foot originating multiple foci on the bones and little reactive bone formation (Aufderheide and Rodríguez-Martín, 1998). Ankylosis of the affected bones, due to destruction of articular cartilage, is also common, and sequestra are rare (Aufderheide and Rodríguez-Martín, 1998). These lesions are similar to those observed in this case study and although actinomycetes can also cause Madura foot, it is more common on the hands, causing lytic lesions of a smaller size and greater number while maduromycosis tends to create larger and fewer foci (Davies, 1958; Magana, 1984). Similarly with the metropolitan cases observed in Portugal (Nobre, 1970 and Cabrita and Figueiredo, 1971 in Cabrita, 1974), as well as suggested by Manchester (1993), only one foot is affected. Fungal grains grow in drier areas than actinomycetes (Dieng et al., 2003; Fahal, 2004), which relates to the climate in southern Portugal. Indeed, between 1000 and 1400 A.D. (Diaz et al., 2011; Cook et al., 2015), commonly called the Medieval Climate Anomaly (Stine, 1994), Europe was drier and warmer than during the Little Ice Age. In medieval times, Estremoz was a small town, and most of its population were predominantly engaged in agrarian occupations and therefore at elevated risk for such infections. A recent case from Madeira Island (Ramos et al., 2013) as well as three maduromycosis infection cases were observed in Portugal, affecting individuals who had never been outside Continental Portugal ((Brandão and Figueiredo, 1963; Nobre, 1970; Cabrita and Figueiredo, 1971) in Cabrita, 1974), so the infection must have originated in Europe. However, it is not clear if the presence of these pathogens is related with movement to and from Africa, especially within the then Portuguese overseas provinces. Nowadays, Madura foot is native to tropical, subtropical and equatorial areas (Bakshi and Mathur, 2008), but in the past these disease patterns could have been different, especially before footwear and modern medicine became common. Assuming that clinical cases can be used as references, it is suggested that in the past Madura foot could have been relatively common in the Mediterranean region, especially when the climate was conductive. It can also be the result of peopleıs´movement from and to Africa and Middle East as well as around the Mediterranean. Thus, the possibility that the individual in the

study became infected outside of Portugal or even beside the European territory cannot be excluded.

Davies (1958) identified four radiological changes in Madura foot: the early change, disease development, the late stage, and the terminal stage. This case study reflects the late stage with the formation of multiple cavities punched out throughout the bone, with large cavities that are few in number, with well-defined margins. This suggests that this case is probably an infection by eumycetoma (Davies, 1958; Magana, 1984). In 2003, El Bagi suggested a new radiographic classification of bone involvement in pedal maduromycosis with seven stages (0–VI), and the changes on the foot in the study are compatible with those described on stage V

Fig.4. Oval shaped trauma (approximately 31×21 mm) at the right parietal.

and VI—a multidirectional spread of the lesions but still without destruction of the foot bones. This skeleton is the only one with this kind of foot lesions of the skeletons recovered from the necropolis in Estremoz.

3.1.6. Other mycotic infections

Blastomycosis, paracoccidiomycosis, cryptococcosis, coccidioidomycosis, histoplasmosis and sporotrichosis can affect the foot bones (Aufderheide and Rodríguez-Martín, 1998; Ortner, 2003). Blastomycosis, paracoccidiomycosis, coccidioidomycosis and histoplasmosis more commonly infect the respiratory tract, and the lesions tend to focus on bones in that anatomic region, but can spread through the blood stream (Aufderheide and Rodríguez-Martín, 1998; Ortner, 2003). Cryptococcosis tend to infect individuals with an inadequate immune response and the lesions commonly focus at bony prominences, cranial bones and vertebrae (Ortner, 2003). Sporotrichosis often affects hands and feet but the lesions are periosteal rather than lytic (Ortner, 2003).

In the present skeleton, besides generalized vertebral osteoarthrosis, evidence of cultural intervention that may relate to the Madura foot pathology is the apparent trepanation in the cranial vault. A noval depression (approximately 31 ×21 mm) exists on the right parietal (Fig. 4), about 18 mm from the lambdoid suture and 53 mm from the sagittal suture. The margins are remodelled, and the external plate of the lesion becomes thinner towards the perforated opening which is not compatible with post-mortem alterations. This asymmetry allows the diagnostic exclusion of enlarged foramina, and the smooth-surfaced remodelled margins and absence of porosity, at or near the lesion (both in the outer and the inner table), indicate that this lesion probably does not have an infectious cause. Since there are not others similar lesions in this individual, it probably is not a metastatic carcinoma or myeloma. Also, there are no radiating lines, which are common in skull fractures or bone spicules circling the lesion. For all these reasons above, the lesion presented is very probably a trepanation. Based on Campillo's descriptions (1977), the method used for the trepanation was probably a scraping perforation through a forward and backward movement on the bone surface until the vault wore away as the perforation is embedded in a crater. Whatever the reason for this trauma, trepanation can be interpreted as a medical intervention. Therefore, a relationship with Madura foot cannot be excluded if the clinical pattern of this infection included weight loss, anaemia and fever common in this pathology.

4. Conclusion

According to the differential diagnosis referred to above this skeleton is probably a Madura foot case triggered by true fungi (maduromycosis) with lesions that are usually found with this type of condition, although there are other possible causes, specifically other mycotic infections. This pathology could also have led to symptoms that would justify therapeutic trepanation. It is suggested that in the past maduromycosis could have been present in Europe, particularly in the Mediterranean region, and especially when the climatic conditions were conducive to its development.

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