Marathon Man: Evidence of Stress Fracture in a Homo antecessor metatarsal from Gran Dolina site (Atapuerca, Spain)

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INTRODUCTION

Perimortem fractures in the cortical bone and is involved in maintaining bone formation throughout life. Bone formation can be physiological, as seen in juveniles, or pathological, as a response to tissue injury. Peri-mortem function is of crucial importance during healing processes with the formation of new bone (Marks and Odgren, 2002). Studies have shown that bone responds to different insults in the same manner (e.g., Schultz, 2003). This lack of specificity makes of periosteal reaction one of the most recorded conditions in archaeological and fossil collections. The type and location of the lesions may help reconstruct subsistence activities, locomotion habits or occupational activities in past and recent populations (e.g., Skinner, 1991; Villoite et al., 2000).

Here we present the paleopathological study of a 4th right metatarsal -ATD6-124-(Fig. 1), assigned to the Early Pleistocene Homo antecessor species from Gran Dolina-Atapuerca site.

METHODS

In addition to the macroscopic technique, we included two microscopic techniques -microtomography (mCT) and scanning electron microscope (SEM) -to describe the lesion and to diagnose the most likely etiology. The fossil was scanned with mCT (MC 60, Scanco Medical) at 70 kV, 140 mA and isotropic voxel size ~30 μm. The image stack was imported into AMIRA software to observe the inner structure and reconstruct a 3D model of the fossil. SEM (FEI, model Quanta 600) was used to characterise the texture of the lesion.

RESULTS

Perimortem lesion. The dome-shaped lesion is highly focal, covers almost entirely the medial aspect of the diaphysis and has created a protuberance on the bone surface. Its dimensions are length ~28.8 mm, width ~8 mm, and a maximum thickness of ~2.5 mm. SEM images revealed a highly porotic and disorganised morphology, identified as woven bone. This morphology would correspond with Ranà’s (2009) classification as thick irregular or class C periostal reaction (Figs. 1 and 2).

Considering the structure revealed disruption of the cortical bone restricted to the medial surface. On paraaxial 2D sections we identified a series of transverse and radiolucent lines (microcracks) that penetrate 2.2 mm into the bone, and a radiolucent area of 12 mm located 40 mm from the proximal epiphysis (Fig. 2).

DIAGNOSIS: STRESS FRACTURE

Fracture is a type of trauma and consists of the disruption of the bone structure, normally involving the adjacent tissues. In maturity bone is in continuous remodelling, osteoclasts cells produce resorption and, subsequently osteoblasts enhance the formation of new bone. Physical activity has been shown to strengthen the bone. However, strenuous, excessive and/or continuous stress during the phase of osteoclastic activity could produce imbalance in the real remodelling mechanism making the bone more prone to fracture (e.g., Ricoba, 2007).

A metatarsal stress fracture corresponds to an indirect fracture (Hawkins, 2005), and it would be the consequence of repetitive forces (e.g., Anderson, 1990; Arangio et al., 1998). The application of stress, namely repetitive forces and load, would create microfractures on the bone. If the stress is maintained microfractures will develop into a transverse fracture (e.g., Rušcheda, 2007). Stress fractures are commonly incomplete, the healing process usually leaves no trace of the fracture and there is a perfect bone alignment. Thus, its diagnosis relies on the identification of other signs such as inflammation, bone turn-over and callus formation (Anderson, 1990). We consider stress fracture as the most likely cause of the ATD6-124 lesion. The identification of microfractures, the lack of cellular involvement and the bone remodelling would be signs in favour of this diagnosis. In addition, the location of the micro-fractures coincides with the weakest point of the metatarsal shaft according to Arangio (1998).

CONCLUSION

We conclude that the lesion displayed by ATD6-124 corresponds to a stress fracture. The lesion would be at the stage of bone turnover from woven to lamellar bone that is, in the process of callus formation. Stress fractures are the consequence of load demands, muscular fatigue or a combination of factors (e.g., Anderson, 1990; Arangio et al., 1998). Stress fractures were first described in soldiers (Leventis, 1993). Nowadays its incidence increase due to fitness popularity and to marathon races. This type of continued, prolonged and strenuous activity puts in risk the integrity of the bones, especially of the lower leg. The ratio between the type of fractures and the metatarsals with 23% (Hartmann, 2011; Recently Pabloes et al., 2013) suggested that the morphology of the H. antecessor left talus (ATD6-93) could be associated to an increased body mass, higher biomechanical demands and great robustness. The stress fracture in ATD6-124 metatarsal implies a failure in accommodating the forces that was receiving. This could be in turn related to a poor anatomical adaption, flat-footedness or specific locomotor practices which may imply high levels of repetitive stress (e.g., O’Brian et al., 2003). Due to the scarcity of pedal fossils we cannot determine if the stress fracture is the consequence of these conditions, as suggested by some authors (e.g., Queen et al., 2002).

As hypothesised for non-human primates and other hominin species pathological events can reflect behaviours (e.g., Lovel, 1991; Skinner, 1991; Gardner and Smith, 2006). For instance, the musculoskeletal markers observed in Neanderthals might indicate stress due to locomotion on hilly terrain (Gardner and Smith, 2006). We believe that the H. antecessor metatarsal fracture was related to muscular fatigue or increased load to the metatarsal heads (e.g., Anderson, 1990; Arangio et al., 1998) due to prolonged and continued walking/running. Moreover, the hilly terrain would increase the risk of lower leg lesions.

REFERENCES


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