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Two case examples of pelvic fractures in medieval populations from central Europe

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Summary - *Pelvic fractures are considered to be uncommon and difficult to treat, even in the modern medical literature. Serious and eventually life-threatening associated injuries may occur, requiring emergency abdominal, vascular or neurologic surgery. Pelvic fractures can also be managed non-operatively; however, a considerable dispute exists on the suitable management strategy. The treatment and healing of such injuries in the bioarchaeological record, is therefore of great interest for anthropological and medico-historical studies. Fractures of the pelvis are rarely reported in the anthropological literature either due to poor preservation of the innominate bone or lack of adequate examination. Here we present two cases of pelvic fractures observed on two adult male individuals from two European medieval sites. They differ in severity and in the pattern of healing. They are both adequately healed and probably had no acute life-threatening consequences, which gives us some insight into the medical knowledge and means of management of past populations.*

Keywords - *Computed tomography, Iliac wing fracture, Femur fracture, Paleopathology.*

Introduction

Traumatic lesions are common abnormalities observed in skeletal remains and in many cases the diagnosis of trauma in archaeological skeletons is easily made. Trauma affects the skeleton in various ways, with fractures being the most common one (Ortner, 2003). Important information, such as the occurrence of domestic accidents, interpersonal violence, occupation related traumas, subsistence strategy, availability of treatment and even nutritional status, can be obtained from the bone healing process (Brothwell, 1961; Larsen, 2002). Therefore, paleopathological studies have the potential to provide insight into the life of past populations (Grauer & Roberts 1996).

Specifically pelvic fractures (PF) are considered even in the modern medicine quite rare and complicated to treat. A literature series regarding management protocols, long-term functional prognosis and retrospective studies exists (Dalal *et al.,* 1989; Heetveld *et al.,* 2004; Geeraerts *et al.,* 2007). Although a rather uncommon injury, the mortality associated with these injuries can be profound. Studies of traumatized patients with PF refer to a mortality rate of 15% to 20% (Young & Resnik, 1990; Ali *et al.,* 2009; Ioannidis *et al.,* 2009) and the estimated risk of death is higher (1,71) than in other bone fractures, e.g. forearm (1,01), ribs (1,27) (Ioannidis *et al.,* 2009). Serious and eventually life-threatening associated injuries may occur, requiring emergency abdominal,

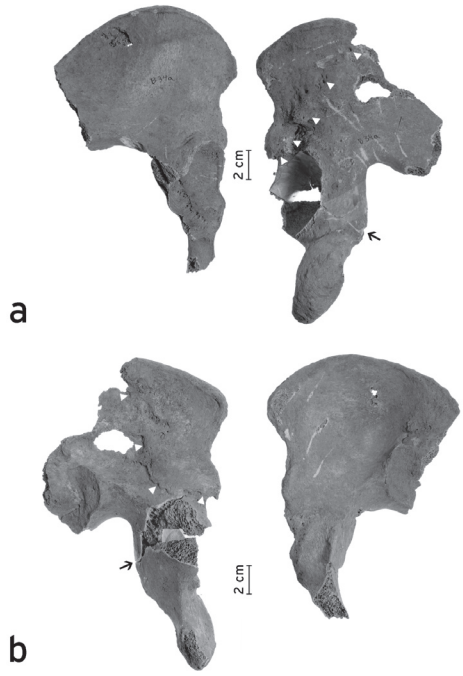

Fig. 1 - Innominate (a) outlet-view, (b) inlet-view fracture site at the iliac wing (arrowheads). Postmortem fracture (arrow). Case 1.

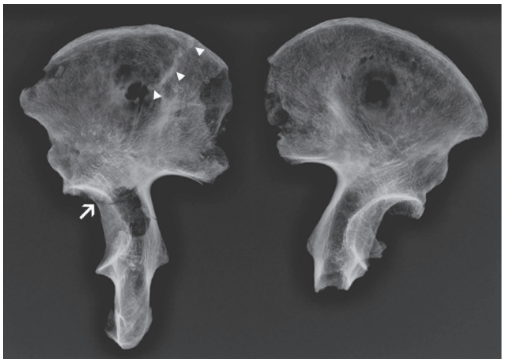

Fig. 2 - Radiography of the right and left innominate fracture site at the iliac wing (arrowheads). Postmortem fracture (arrow). Case 1.

vascular or neurologic surgery (Mucha & Welch 1988; Geeraerts *et al.,* 2007). Specific PF can be managed non-operatively, however, a certain medical treatment dispute exists specific to the proper strategy for nonunion or malunion of PF (Dujardin *et al.,* 1998; Switzer *et al.,* 2000; Burkhardt *et al.,* 2005; Abrassart *et al.,* 2009; Ali *et al.,* 2009, Taller *et al.,* 2009).

The presence and management of such injuries in the bioarchaeological record is of interest for anthropologists, medical historians and physicians. However, PF have received little attention in the anthropological literature. There is no published data about this kind of trauma in paleopathology review papers (Lovell, 1997), specialized textbooks (Ortner, 2003; Mann & Hunt, 2005) nor in fracture-pattern research papers (Lovejoy & Heiple, 1981; Alvrus, 1999; Walter *et al.,* 1999; Judd & Roberts, 1999; Djuric *et al.,* 2006; Dommet & Tayles, 2006; Paine *et al.,* 2009). This low percent of paleopathological data probably derives from the difficulties in identification based on the taphonomic condition of the pelvis in comparison to other bones of the skeleton, i.e. as a consequence of postmortem fragility. The "fundamental conceptual problems" such as selective mortality and hidden heterogeneity in risks described by Wood and colleagues (1992) should be also considered as biased when interpretating this lack of data concerning traumas to particular parts of the skeleton. In the present study, we present two cases of PF from two European medieval sites. They offer valuable insight on the treatment and clinical management of such complicated traumas in this specific temporo-spatial setting.

Material and Methods

The first case (grave # 34a) concerns a partially preserved skeleton of an adult male, between 40 and 60 years old. Most of the lower limbs were recovered whereas parts of the axial skeleton and the upper limbs were not preserved. The skeletal material (54 individuals) comes from a historic monastery in Dalheim, Germany most likely dated to the mid 11th century AD (radiocarbon dating by Institute for Particle Physics Swiss Federal Institute of Technology, Zurich). The excavation area and burial were described in previous studies (Hofmann *et al.,* 2008). The demographic profile

of the exhumed population included 21 females, 26 males and 7 of unknown sex. All age groups from infants to older adults were represented.

The second case (grave #454) concerns a male individual of about 40 years of age. The skeleton was complete and presented multiple pathological conditions. The skeletal material comes from a medieval cemetery in Canton Graubünden, Switzerland most likely dated to the 11th - 15th century AD based on archaeological data and radiocarbon dating (Institute for Particle Physics Swiss Federal Institute of Technology, Zurich). Recovered from the cemetery were 404 well-preserved individuals, 152 females and 123 males, 118 unsexed sub-adults as well as 11 unsexed adults. According to age determination, the population included individuals ranging in lifespan between infants and older adults (Papageorgopoulou, 2010).

In both cases, sex was determined using standard morphological criteria (Harsányi & Nemeskéri, 1964; Ubelaker, 1978; Workshops of European Anthropologist, 1980; Bass, 1995). Age at death was estimated according to the "complex method" (Nemeskéri *et al.,* 1960; Acsàdi & Nemeskéri, 1970; Workshops of European Anthropologist, 1980; Lovejoy *et al.,* 1985). All pathologically affected bones from both cases were radiographically examined (University Clinic Balgrist, Zurich, Switzerland). Radiographic recording was performed in anterior-posterior views. Computed tomography scans were performed in the coronal plane (Phillips Brilliance Multislicer 40). Continuous scans were performed using a slice thickness of 2 mm.

Results

Case 1

Of all exhumed skeletons with preserved innominates (n = 60) in Dalheim, only one displayed a PF. The left innominate presented with an oblique fracture of the posterior ilium extending laterally from the sacroiliac joint, near the iliac crest, crossing above the acetabulum to the anterior inferior iliac spine, in anatomic alignment and with a moderate callus (Fig. 1). The articular surface of the head of the left femur and acetabulum were normal. The right innominate had normal

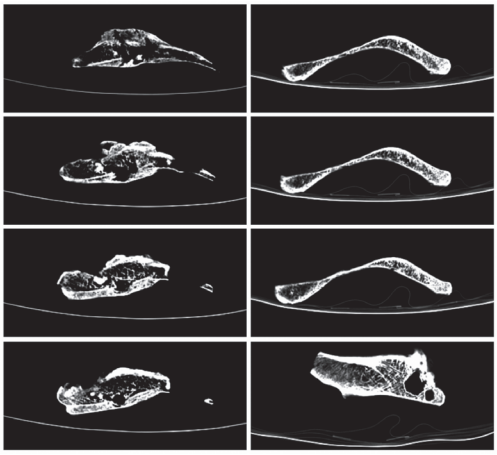

Fig. 3 - CT scans, coronal plane, of the left innominate with an old fracture and callus. Case 1.

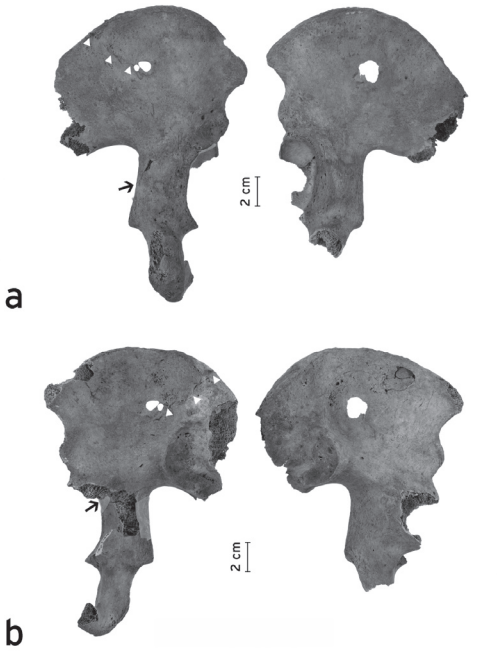

Fig. 4 - Innominate (a) outlet-view, (b) inlet-view fracture site at the iliac wing (arrowheads). Postmortem fracture (arrow). Case 2.

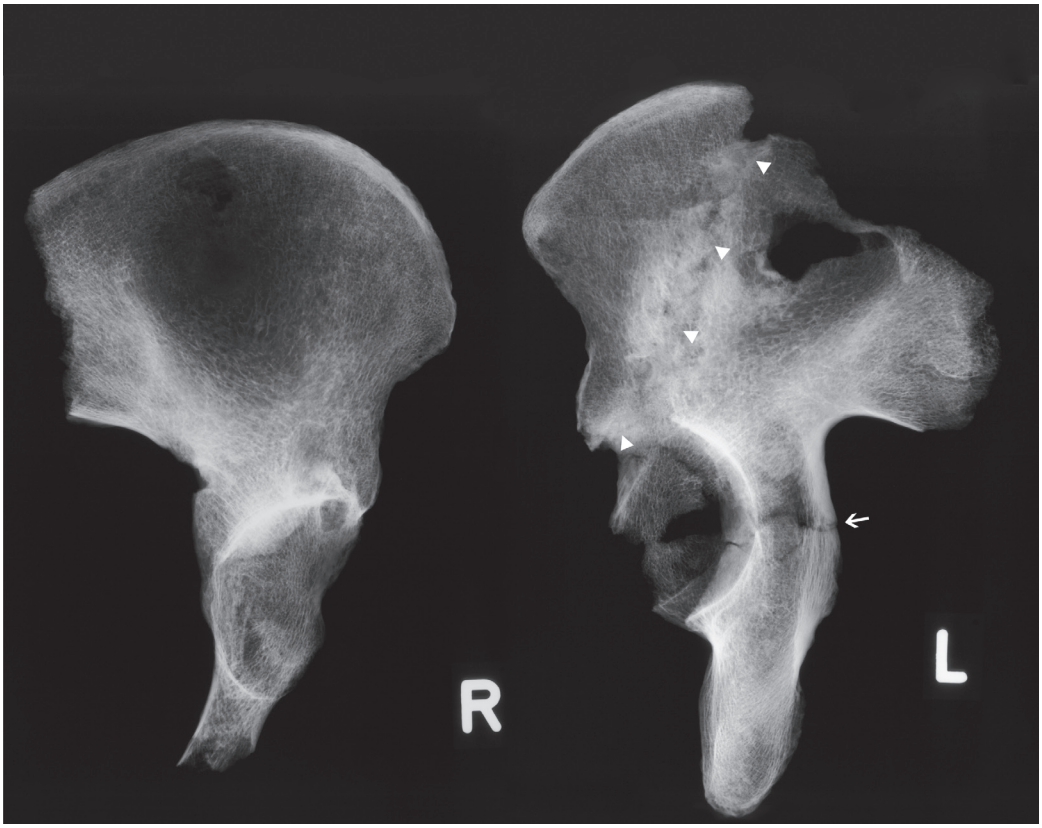

Fig. 5 - Radiography of the right and left innominate fracture site at the iliac wing (arrowheads). Postmortem fracture (arrow). Case 2.

morphology. The femurs were in a very good condition with no visible pathology. The preserved tibiae and fibulae were also free from pathology.

Conventional X-ray and CT images mainly confirmed the macroscopic appearance. Adjacent to the fracture line, (which does not appear to be fully consolidated and still exhibits a mild dislocation, Figs. 2 and 3) one finds cloudy patches of increased sclerosis consistent with callus formation. Bone remodelling took place and ragged fracture edges are no longer visible. There are no obvious signs of major bone remodelling specific to infection or reactive osteopenia. Some areas of largely compact bone such as the iliac crest and acetabular region, are only partially preserved. Additionally, there is clear diagenesis-related trauma present on the bone.

Case 2

Of the 404 exhumed skeletons with preserved innominates (n = 336) from Tomils / Sogn Murezi, only one displayed a PF. The right ilium presented an oblique fracture of the posterior ilium extending laterally from the sacroiliac joint, near the iliac crest, crossing obliquely up to the middle part of the bone. The PF was in anatomic alignment and had a moderate callus (Fig. 4).

Radiological examination revealed that the fracture line in this individual (Figs. 5,6) appeared to be completely consolidated in comparison to case 1 and was represented by a well-defined band of radiodensity. No adjoining zones of radiolucency nor ongoing bone remodelling was visible. Also, partial postmortem damage including a fracture and missing bone areas were visible.

Besides the right innominate fracture, we observed fractures to the left femur, to two left ribs probably the 8th and the 9th and a fracture of the first left metatarsal. The cervical and lumbar vertebrae were affected with spondyloarthritis, the left patella with eburnation and both tibiae with a light periosteal reaction on the diaphysis. The femur fracture was located on the proximal third of the diaphysis a few centimetres below the subthrochanteric region with good callus formation (Fig. 7). The strong abduction of the proximal fragment led to a medial angulation, producing a varus and a shortening of the bone (Fig. 8). The articular surface of the femoral head and acetabulum were free of pathology.

In addition to the varus dislocation in the fractured femur, there was a well-defined band of radiodensity that allows one to postulate the fracture zone (Fig. 8). A prominent adjoining callus formation is visible, but there was no clear evidence of major subsequent ongoing bone remodelling. However, in the CT scans, a more patchy and irregular trabecular alignment can be found, suggesting at least a partially prolonged subsequent bone remodelling (Fig. 9).

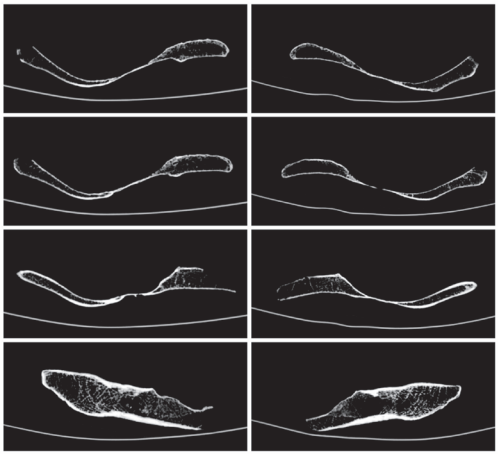

Fig. 6 - CT scans, coronal plane, of the left innominate with an old fracture and callus. Case 2.

Discussion

We report two PF observed in male adult individuals exhumed from two medieval sites in central Europe. Both fractures were observed in the ilium and correspond to the typical iliac wing fracture (IWF) type reported in the medical literature, classified by the Orthopaedic Trauma Association committee as 61-A2 (OTA, 1996; Switzer *et al.,* 2000; Abrassart *et al.,* 2009). Iliac wing fractures are uncommon and difficult to treat (Switzer *et al.,* 2000). There is little information in the literature about adult IWF (Abrassart *et al.,* 2009), although the first descriptions of such injuries had been reported in 1751 (reprinted Duverney, 1996). In the pediatric literature, IWF are reported in relation to bicycle or lap-seat belt trauma (Huittinen & Slatis, 1972; Amr *et al.,* 2002). Retrospective studies of a consecutive series of polytraumatised patients identified iliac wing traumas in about 2% of all patients. Males were more affected than females and had a mean age of 38 years (Switzer *et al.,* 2000; Abrassart *et al.,* 2009). This data is similar to the data from the two medieval populations reported here, although the rate is lower in the archaeological populations.

PF are classified as stable or unstable: a stable fracture involves one break-point in the pelvic ring, whereas an unstable fracture involves two or more break-points. The first case corresponds to an oblique, extensive, consolidated fracture of the iliac wing with mild dislocation. The superior and inferior pubic rami as well as the sacrum are missing. Therefore, we cannot make any further assumptions whether it was stable or unstable. In the second case, there was no other pelvic skeletal element fractured, e.g. pubic rami, and the fracture did not extend into the sciatic notch, the sacrum or the acetabulum. Such traumas are usually stable and do not lead to pelvic ring disruption (Abrassart *et al.,* 2009).

Another categorization of PF as "open" or "closed" depends on whether open skin wounds are present or not (Resnick, 2002). We assume that in both cases the wound was closed, since we found no evidence of bone inflammation. In modern clinical data, open fractures are less common among IWF (20%) (Abrassart *et al.,* 2009). Regarding the direction of the injurious forces,

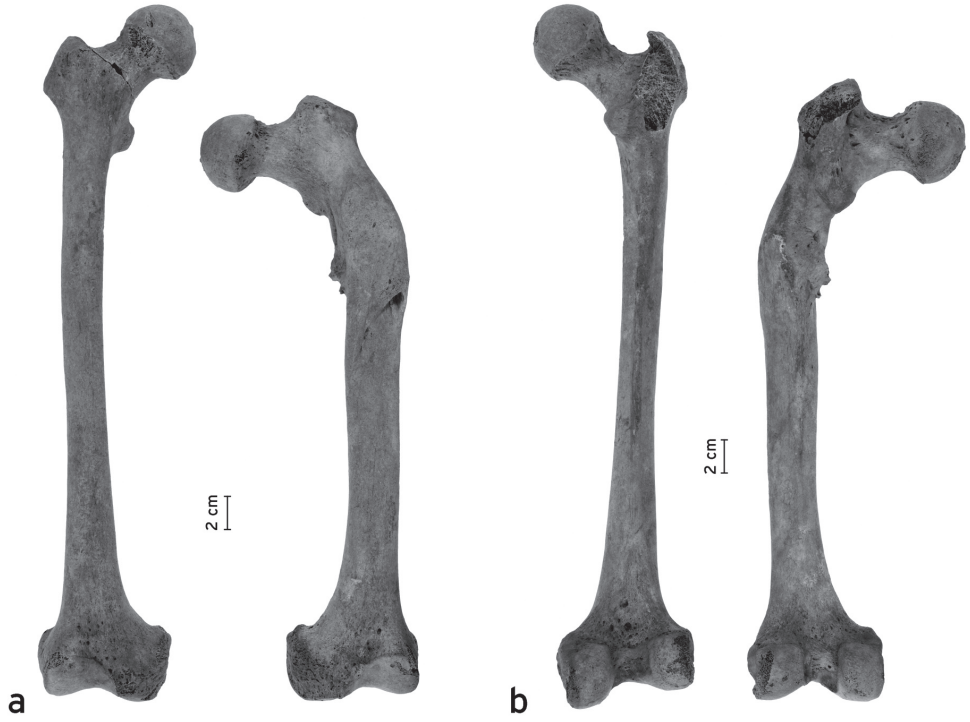

Fig. 7 - Right and left (a) femur ventral view, (b) dorsal view. Case 2.

we would classify the fractures as a less severe type in the lateral compression group, where oblique iliac wing fractures can be observed in isolation (Young *et al.,* 1986; Young & Resnik, 1990). Nonetheless, such categorizations on complex bone elements such as the pelvic ring, based on fragmentary material and lacking soft tissue, should be viewed with caution. We tried to reconstruct these cases based on modern clinical data, but we also have to consider the unavoidable limitations of such reconstructions.

Healing of IWF occurs without difficulty due to the excellent vascularity, supplied by good muscle coverage, and because there are no rotations or vertical instability of the pelvis (Abrassart *et al.,* 2009). The potential risks arising from such traumas relates mainly to the non-skeletal injuries involving the visceral, vascular, urologic and gynecologic systems. Major trauma with associated injuries to the hip and other bones, predisposes to complications such as malalignment (rotational or angular deformity and femoral shortening), vascular injury, infection, thrombophlebitis, fat embolization, and chest and abdominal injuries (Poole *et al.,* 1991; O´Sullivan *et al.,* 2005; Vásquez *et al.,* 2008). Nerve lesions are rare, but have been also reported in one case (Switzer *et al.,* 2009). Based on modern data, it is quite probable that the two medieval "patients" suffered from one or more soft tissue injuries.

Treatment methods of fractures in ancient times were very similar to those of modern times not only in principle, but also in practice (Clark, 1937; Künzl, 2002). There is historical evidence for fracture treatment in medieval Europe (Clark, 1937; Grauer & Roberts, 1996; Jankrift, 2005). Orthopaedic surgeons, known as bone-setters, and barber surgeons manipulated, splinted, and

even used extension methods by windlasses, levers, ratchets, and pulleys. A mild fracture may heal in several weeks without surgery (Schultz, 1961). IWF in particular exhibit a high rate of successful non-operative treatment (Abrassart *et al.,* 2009). We can assume that the two PF were treated to a certain degree. The fractures were well healed indicating that they had occurred years prior to the individuals´ death. In the second case, the characteristic femoral shortening and varus suggests that fracture reduction, e.g. by extension was not attempted or had failed. It is probable that the individual was treated in recumbence, staying in bed for a long time until the pain had subsided. That could explain the good consolidation of the IWF.

The etiology of IWF in modern populations is associated with high energy trauma, including road traffic crashes and falls from great heights (Vásquez *et al.,* 2008) or spontaneously after minor falls in people with bone-weakening diseases. It is difficult to reconstruct the exact etiology of the medieval fractures, but they may also have been caused by similar high intensity forces. Both IWF were oblique suggesting that indirect forces were responsible, e.g. a blunt blow such as an animal kick (Huittinen & Slätis, 1972) may be applicable in the first case, in which no other bone was fractured and a fall on the left side of the body e.g. fall from a building or a cart in movement on the second case with the multiple fractures. Documentation on daily activities of these two medieval populations include many risk factors that may lead to such traumas, e.g. ploughing fields, carting goods, felling trees, herding animals (Segin, 1935; Rüthing, 1980; Pieper, 2003; Papageorgopoulou, 2009). Both individuals exhibited no signs of bone-weakening diseases, so a fracture due to osteoporosis is unlikely.

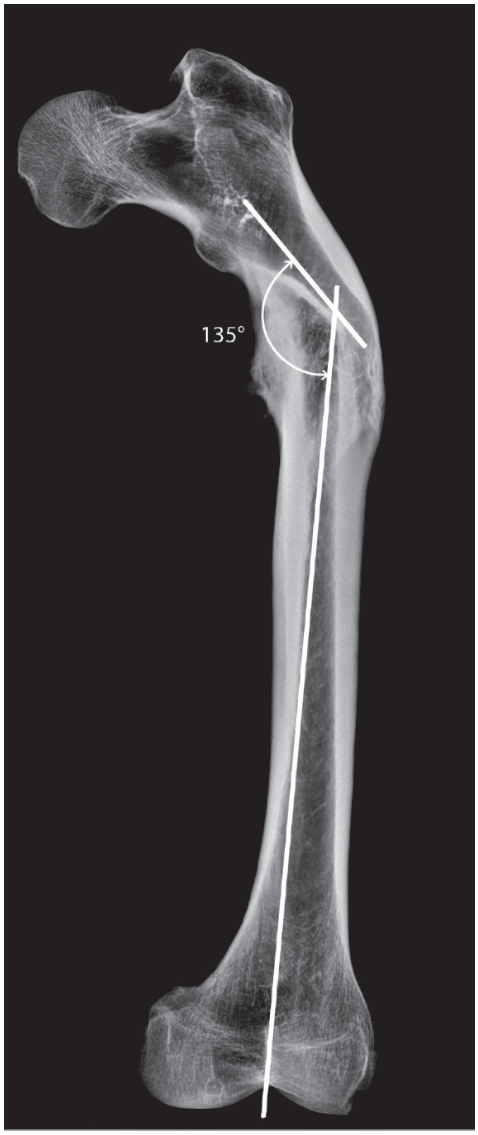

Fig. 8 - Radiography of the left femur with the varus angle (135˚). Case 2.

Conclusion

In these two historic cases, we could peer into the wide spectrum of IWF. It has been shown that PF, although rare, are present in archaeological populations and could heal successfully. The interpretation of the two cases entails limitations due to the fragmentary nature of the first case, but it is clear that both fractures were not fatal. Regarding the available means and the times, it is quite astonishing how well these traumas were managed, since both individuals survived the injuries. This reveals the high level of medieval medical knowledge and is

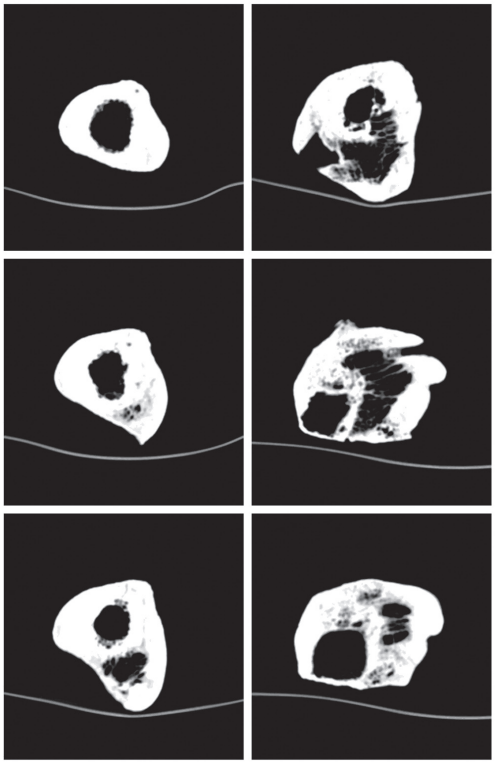

Fig. 9 - CT scans, coronal plane of the left femur. Case 2.

specifically of interest for medico-historic research. The present paper may enlighten modern discussions about treatment strategies, operative versus non-operative management, by offering a different dataset to modern clinical research. It also gives some information on domestic and/or occupation related traumas, convalescence and survival chances, which is significant within a historic context.

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