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Osteobiography of a 19th Century Elderly Woman with Pertrochanteric Fracture and Osteoporosis: A Multidisciplinary Approach

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A B S T R A C T

In this paper the osteobiography of an elderly woman recovered from a cemetery tomb where she was buried in 1850, affected by hip fracture and osteoporosis, is described. The overall anthropological characteristics of the individual have been investigated. Macroscopic, radiographic, tomographic, microscopic, and chemical and structural examinations have been performed to give a detailed account of the condition of the skeleton. A non-union pertrochanteric fracture not surgically treated and probably due to senile osteoporosis was diagnosed. The consequences of the fracture to the bones show that this individual likely survived several years following the injury. The osseous features we describe (remodelled bone at the fracture site, asymmetry of entheseal changes likely related to the particular walking pattern of the individual) may be useful in personal identification of skeletons of legal interest. Regarding the recognition of osteoporosis in unearthed skeletons, our study underlines that the cortical thickness, microscopic features, degree of crystallinity and Ca/P ratio represent more useful elements than the mean bone density, mineral/matrix ratio and mineral maturity, which are more sensitive to diagenetic changes that affect the mineral phase post-mortem.

***Key words**: palaeopathology, non-union fracture, pertrochanteric fracture, osteoporosis, bone morphology, cristallinity*

Introduction

Physical anthropologists study human skeletons using specific methodologies to reconstruct the biological profile and »history« of individuals (age, sex, pathological conditions, amount of mechanical loading from occupational activities, trauma suffered during life or after death) and the characteristics of populations (demographic structure, epidemiological aspects of diseases, etc.). The osteobiography of individuals, besides the anthropological interest in the reconstruction of past life styles and conditions in the case of ancient human remains,

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represents an important source of information in the forensic field. In fact, it can provide elements for individual identification through the comparison of specific physical characteristics, information on the life history and clinical record of unknown missing subjects. However, regarding the pathological conditions affecting the skeleton, it should be noted that the clinical and palaeopathological diagnoses rely on different elements, and are not directly comparable. In the clinical field the diagnosis can take advantage of the symptoms, anamnesis, observation of soft tissue involvement, laboratory exams and radiographic observation of bone. The palaeopathological diagnosis is based essentially on bone macroscopic, radiographic and microscopic observations; sometimes also chemical, biochemical or molecular analyses are possible, depending on the preservation state of the remains. In fact, bones that have rested in the earth or in closed environments (tombs, etc.) for a long period of time undergo diagenetic processes that can affect the macro- and microscopic morphology, organic and mineral contents, etc. Thus, in some skeletons of forensic interest, the diagnostic methods of palaeopathology are more appropriate than the current clinical procedures, and the effects of taphonomic diagenetic processes must be taken into consideration.

In this frame we undertook an overall anthropological analysis of an identified 19th century pathological skeleton recovered from an underground cemetery tomb, using a multidisciplinary approach to reconstruct its osteobiography. The skeleton refers to an elderly woman showing specific pathological features, namely a non-united pertrochanteric fracture not surgically treated and osteoporosis. We focused on these pathological conditions, which were examined starting from the macroscopic paleopathological analysis, with the contribution of microscopy, radiology and computed tomography (CT). Chemical and structural characterization of the cortical and trabecular bone have also been carried-out. The results are interpreted in the light of the pathological, as well as diagenetic changes to the bones. Thus, the aim of this study is to provide a reference case for aged women with trochanteric fractures treated conservatively and osteoporosis, underlining the possibility of obtaining information about relevant aspects, such as the timing of fracture onset and the effect of diagenetic changes on some osseous features that could be taken into consideration for osteoporosis diagnosis in unearthed skeletons.

Materials and Methods

The skeleton under study is that of Maria Carlotta Pisani (1769–1850), exhumed by our research group in 2006 as part of a project to recover and study the remains of the famous castrato Farinelli[1], her great-uncle, who rested in the same tomb at the Certosa cemetery of Bologna. The tomb was bought by Maria Carlotta Pisani (MCP) in 1845 to accommodate the mortal remains of her beloved great-uncle, with the intention of being buried in the same place after her death[2]. Documents from the cemetery archives attest that MCP died on the 4th of January 1850, and was buried according to her will on January the 6th. The marble plaque on the tomb bear the inscription that she dedicated to her great-uncle, as well as another epigraph that was added by her heirs in her remembrance after her death. The underground brick tomb contained the remains of MCP and those of Farinelli, accumulated at her feet when her body was buried (Figure 1). There were many woody remnants of Maria Carlotta's casket, while Farinelli's remains were without any protective structure.

Fig. 1. The skeletal remains of Maria Carlotta Pisani (right) and Farinelli (left) at the opening of their tomb.

Although the skeleton of MCP was in its undisturbed primary burial, the state of preservation was poor (Figure 2) on account of the microclimatic conditions of the tomb and water infiltration, as shown by the concretions

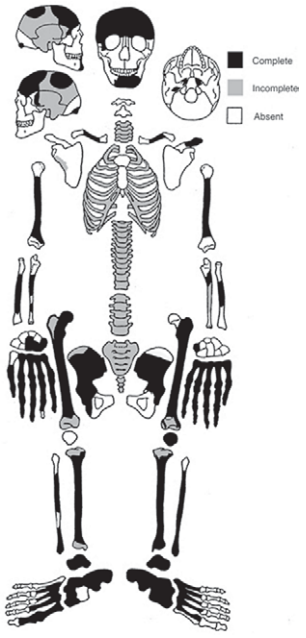

Fig. 2. State of preservation of the skeleton of Maria Carlotta Pisani.

TABLE 1
SCANNING PARAMETERS USED FOR THE FEMURS OF MARIA CARLOTTA PISANI AND OF THE COMPARISON SAMPLE

Scansion modality	Slice thickness (mm)	Reconstruction increment (mm)	SFov (mm)	DFov (mm)	Reconstruction algorithm	Kv	mA	sec
Elical	2.5	2	250	180	Kernel, Bone	100	80	0.8

SFov – Scan Field of view, DFov – Display Field of view

found near and on the bones. The cortical bone of the preserved elements was often eroded. The left femur, affected by the aforesaid lesion that deprived it of the head and neck, has a lacunose distal epiphysis. The right femur is lacking the greater and lesser trochanter and parts of the distal epiphysis due to *post mortem* taphonomic events. There remains a fragment of the left acetabulum, including the posterior part of the lunate surface, while the more complete right acetabulum lacks the anterior border.

The age and sex of the individual, although known, were assessed according to standard anthropological methods[3,4]. The bone measures and indexes were calculated according to Martin and Saller[5] and Olivier[6]. The estimation of living height based on the tibiae, the only bones whose length could be measured, was based on Pearson[7] and Olivier et al.[8], who used French cadavers of the 19th and 20th c. to develop their methods.

The palaeopathological analysis of the femora and coxal bones was carried out by macroscopic and radiographic observation. To assess the relationship between the pathology under study and the general conditions of the individual, we extended the observations to all the preserved skeletal elements. In particular, we scored the entheseal changes according to standard methods[9,10], and we recorded other possible pathological alterations of the bones and joints.

We also performed a CT analysis (Scanner CT Multislice; Bright Speed 8 Slices, General Electric, USA) on the femurs of MCP and, in order to have a first comparison, of other female skeletons belonging to individuals that died between 1898 and 1932 (n.13: 51 y.; n.45: 30 y.; n.52: 82 y.; n.54: 30 y.; n.75: 58 y.; n.81: 80 y.) (Frassetto collections, Museum of Anthropology, University of Bologna) and exhumed from the Certosa cemetery in Bologna. The medio-lateral periosteal (D) and endosteal (d) diameters were measured at the bone mid-length. An estimate of the cortical thickness (CoT) was obtained as (D–d)/2. We also obtained densitometric values on the medial condyles immediately below the compact bone, the only comparable area rich in cancellous bone. The protocol used consists of a scout view and a series of sequences CT scan multislice on the bones examined. The scanning parameters are shown in Table 1.

Morphological analyses were performed on specimens of cancellous and cortical bone taken from the remains of MCP, including samples from the fracture area. Some of the samples were embedded in a methyl methacrylate-based resin (Technovit 9100N). A sawing and grinding system (Remet, Bologna, Italy) was used to cut the specimens to obtain 100 micron thick sections. Some sections were then stained for observation under a light microscope (LM) (Leitz Orthoplan light microscope, Leica Microsystem Inc., Bannockburn, IL, USA), while others were processed for observation under a scanning electron microscope (SEM) (SEM Philips 515, Eindhoven, Holland). Other bone specimens were directly processed for SEM investigations.

Some samples were selected in different areas of the skeleton for structural and chemical analyses. The cortical and cancellous regions were separated, and crushed in a mortar before analyses. X-ray diffraction analysis was carried out by means of a PANalytical X'Pert PRO powder diffractometer equipped with a monochromator in the diffracted beam. CuKα radiation was used (40 mA, 40 kV). The 2θ range was from 10 to 60° at a scanning speed of 0.75°/minute. In order to evaluate the coherence length of the HA crystals, further X-ray powder data were obtained in the relevant region of 2θ by means of step scans using a fixed counting time period of 10 s and a scan rate of 0.020°/step. For IR adsorption analysis, 1 mg of the powdered samples was carefully mixed with KBr (250 mg, infrared grade) and pelletized under a pressure of 10 tons for 2 minutes. The pellets were analyzed using a Nicolet 380 FT-IR spectrophotometer to collect 32 scans in the range 4000–400 cm^{-1} at a resolution of 4 cm^{-1}. Thermogravimetric analysis was carried out using a Perkin Elmer TGA-7. Heating was performed in a platinum crucible in air flow (20 cm^3/min) at a rate of 10 °C/min up to 950 °C. The samples weights were in the range 5–10 mg. Calcium and phosphorous contents were determined by means of a Dionex DX100 chromatography system equipped with a Dionex CD20 conductivity detector.

Results

The skeletal markers of age and sex are consistent with the personal data in our possession, confirming the identification of the skeletal remains as those of MCP. In particular, the preserved parts of cranial sutures were almost completely closed. The auricular surface of the ilium, in spite of *post mortem* damage, showed the features typical of advanced age (irregular surface, porosity and marginal lipping). The coxal bones showed female characteristics, such as broad greater sciatic notch and marked preauricular sulcus. The frontal bone showed smooth glabellar and supracialiar regions and marked

frontal eminences. The mandible shows small and rounded mentum. The estimation of living height gave values between 147 and 151 cm. The skeleton was fairly gracile, as indicated by the index of robusticity calculated from the tibiae (sx: 18.56; dx: 18.24; mean value for the Caucasoid population[6] from 20 to 21). The pathological and other anatomical features displayed by the skeleton are described below.

Macroscopic and radiographic analyses

The left femur lacks the neck and head. The surface of the lesion is covered by cortical bone. It is almost vertical, extending from the base of the neck to almost all of the lesser trochanter. Its anterior edge roughly follows the border of the articular capsule, reaching the extracapsular area in the inferior part; the posterior edge largely follows the course of the intertrochanteric crest (so that only part of the posterior wall of the lesser trochanter is preserved) and ends in the extracapsular area. The lesion surface is ellipsoidal, with a major axis of ca. 50 mm oriented postero-inferior to antero-superior and a minor axis of ca. 20 mm. However, the perimeter of this area is curved in the infero-medial part anterior to the lesser trochanter, describing a loop that seems to divide the area into a small ovoid surface near the lesser trochanter and a larger, roughly ovoid surface superior to it (Figure 3). The margins are marked by discontinuous rugose ridges, whose maximum development is observed near the lesser trochanter. The surface is relatively smooth, with only slight irregularity and some small osteolytic areas (Figure 3). In posterior view, a fracture line (probably of taphonomic origin) runs vertically from the superior apex of the lesser trochanter to the apex of the greater trochanter and then descends vertically to the superior limit of the gluteal tuberosity, where it deviates transversely toward the medial part for ca. 10 mm (Figure 3). The preserved fragment of the left acetabulum presents a remodelled and porotic surface, which nevertheless preserves the concavity of the articulation (Figure 4).

Fig. 3. Fracture surface in the left femur of Maria Carlotta Pisani: medial view (left) and posterior view (right). The arrows indicate the position of the lesser trochanter.

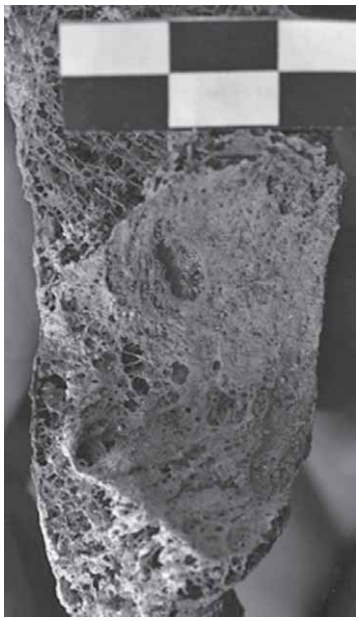

Fig. 4. Left acetabulum of Maria Carlotta Pisani with remodelled and porotic surface. Note the concavity of the articular surface.

Radiographic examination of the left femur at the point of fracture shows an area of bone repair with a radiolucent profile. The margins of the corresponding acetabulum do not have a well-defined border, evidently due to osteolytic resorption (Figure 5).

Despite the advanced age of the subject, the contralateral bones do not exhibit noteworthy alterations.

Macroscopic observation of the bones of MCP reveals a diffuse loss of bone tissue: rarefaction of the trabeculae of the spongy bone is well visible in the vertebral bodies and epiphyses of the long bones, while the shafts exhibit

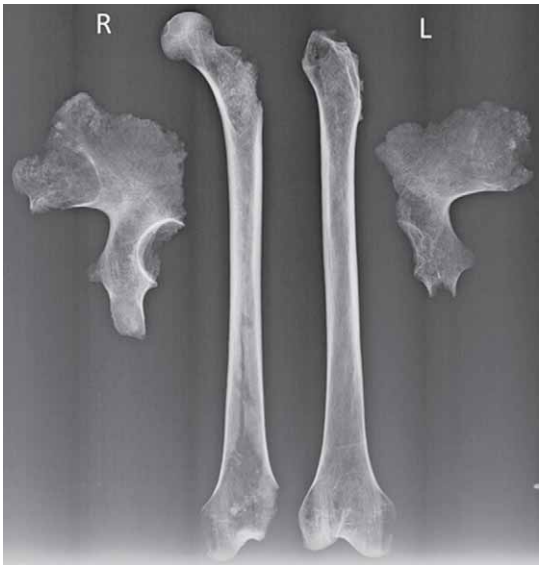

Fig. 5. Radiography of the femora and coxal bones of Maria Carlotta Pisani.

marked thinning of the compact cortical bone. The radiography of the femora and coxal bones shows increased radiotransparency due to rarefaction of the trabeculae, observed mainly in the spongy bone of the iliac wing of the coxal bones (Figure 5). In the femora, especially the left, the increased width of the medullary canal of the shaft is quite appreciable.

Unfortunately, the loss of consistency of bone tissue favoured the destruction of the more fragile parts of the skeleton. Only some vertebral fragments strengthened by processes of ossification and bone fusion remain. In particular, there is fusion of the articular facets of the vertebral arches of two lower thoracic vertebrae, with deviation of the spinal curvature and scoliosis. This is suggested by the irregular overlap of the articular facets, also showing osteophytosis around the rims. Moreover, still in the lower thoracic region, fusion between a rib and the articular facet of the vertebral body is observed. Other joints and most of the entheses were not recordable. In the lower limb there is strong bilateral development of the femoral attachments of *mm. gluteus maximus* and *vastus medialis*, but in both of them enthesophytes are present only on the right side. The tibial enthesis of *m. soleus* shows strong bilateral development, accompanied by enthesophytes.

CT analysis

Data from CT examination are shown in Table 2. The cortical thickness decreases in general with age, the left femur of MCP showing the lowest value. The densitometric data show higher values for MCP in comparison with the more recent skeletons of the Frassetto collection, which show a general decrease with advancing age.

TABLE 2
METRIC AND DENSITOMETRIC DATA OBTAINED FROM THE CT ANALYSIS OF THE FEMURS OF MARIA CARLOTTA PISANI (MCP) AND OF THE COMPARISON SAMPLES. MEASURES DONE WITH W=2000 HU, L= –440 HU

Femur	Age at death	Side	D	d	CoT	Mean density[a] (HU)
MCP	80	R	22.1	12.0	5.1	170
		L[b]	22.5	15.0	3.8	180
n. 45	30	R	23.4	10.5	6.5	120
		L	23.6	11.6	6.0	120
n. 54	30	R	24.3	10.8	6.8	130
		L	23.7	11.5	6.1	100
n. 13	51	R	22.3	10.6	5.9	140
		L	22.3	11.6	5.4	120
n. 75	58	R	25.0	11.35	6.9	115
		L	25.0	11.0	7.0	115
n. 81	80	R	23.8	14.6	4.6	118
		L	22.2	11.7	5.3	100
n. 52	82	R	23.6	14.3	4.7	70
		L	24.4	14.3	5.1	80

D – medio-lateral periosteal diameter, d – medio-lateral endosteal diameter, CoT – cortical thickness calculated as (D–d)/2, HU= Hounsfield unit; [a] Mean ROI on medial condyle: area = 38 mm^2; [b] Pathological specimen

Microscopic analyses

Observation of the resin-embedded specimens disclosed radical changes in bone tissue morphology (Figs. 6 and 7). In particular, the thin cortical bone tissue from all the observed samples contained material of probable taphonomic origin forming an almost continuous layer of coating (data not shown). The bone surfaces, namely the periosteal surface, were highly irregular. The bone contained numerous macro- and microscopic lacerations with jagged edges and were often full of resin (Figure 6a). The macroscopic lacerations tended to be oriented along the bone lines of least resistance (e.g. the external perimeter of the osteons and the spaces between adjacent lamellae) (Figure 6b). The microscopic lacerations appeared as oval gaps with irregular margins and parallel

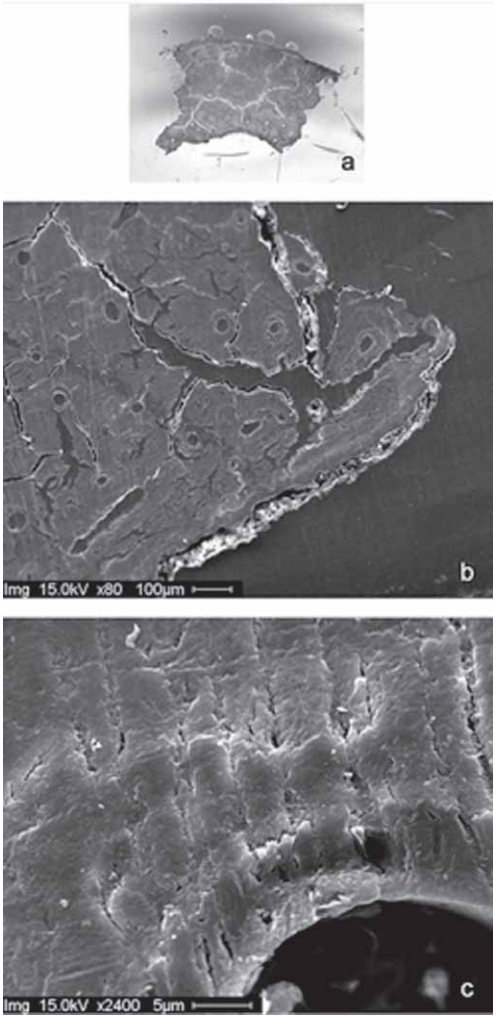

Fig. 6. Morphology of compact bone of Maria Carlotta Pisani. a) Bone section under LM. b) Bone section under SEM. c) Bulk sample of bone under SEM.

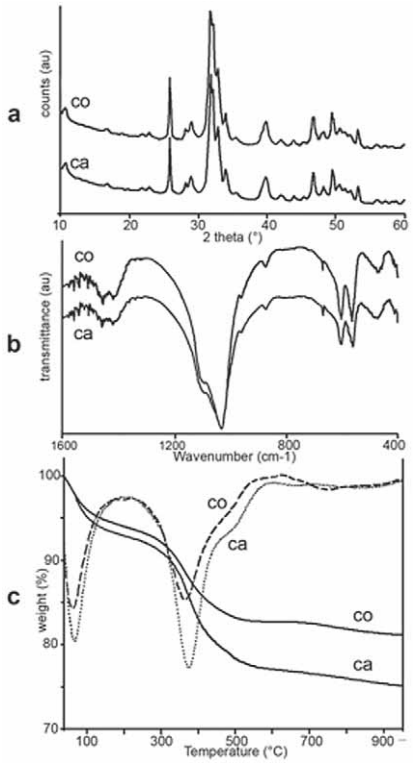

Fig. 7. Powder X-ray diffraction patterns (a), Fourier Transform Infrared Spectroscopy (FTIR) absorption spectra (b), and Thermogravimetric-Differential Thermogravimetric TG-TDG plots (c) of cortical (co) and cancellous (ca) bone.

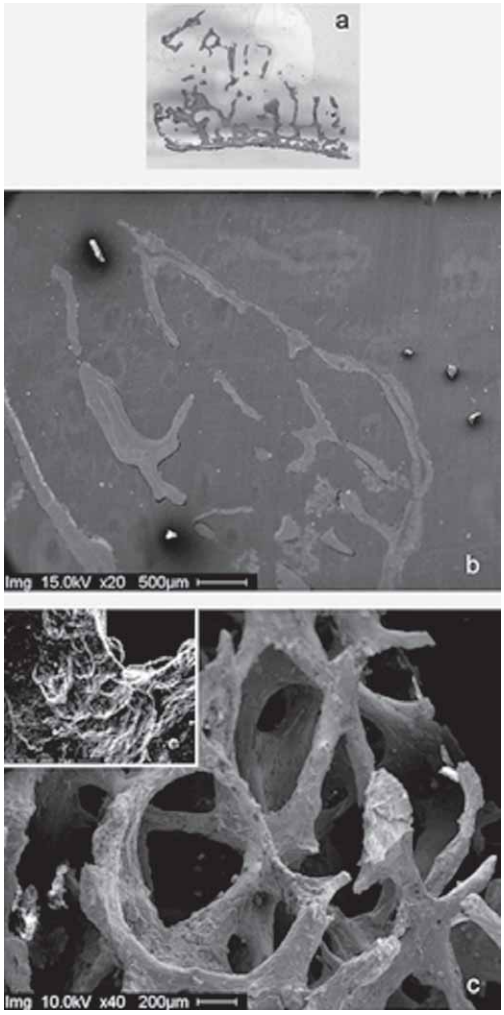

Fig. 8. Morphology of spongy bone of Maria Carlotta Pisani. a) Bone section under LM. b) Bone section under SEM. c) Bulk sample of bone under SEM; in insert a detail of a trabecula showing Howship lacunae.

fracture lines perpendicular to the largest axis of the lamellae. The lamellae appeared typically loose (Figure 6c).

The cancellous bone specimens also had a coating of taphonomic material uniformly distributed over the surface (Figure 7b). The bone marrow spaces appeared large and anastomized, while the bone trabeculae were narrow and sparse (Figure 7a and c). The trabeculae surface often revealed a series of cavities similar to Howship lacunae (Figure 7b), interrupting the bone surface linearity especially in the regions of major trabecular thinning.

Chemical analysis

The inorganic phase content of the samples was determined from the results of thermogravimetric analysis. The TG-DTG plots display three thermal processes: loss of water between 25 and about 200 °C, decomposition of collagen and combustion of the residual organic components between 200 and 600 °C, and removal of carbonate ions from the inorganic phase between 600 and 800 °C[11] (Figure 8c). According to the weight losses, the inorganic phase content amounts to 75±1wt% for cancellous bone and to 80±1wt% for cortical bone, whereas the organic phase content accounts for 16±1wt% for cancellous bone and for 11±1wt% for cortical bone. The greater amount of organic phase in cancellous bone is responsible for the different shape of the DTG peak between 200 and 600 °C that shows a better resolved shoulder around 500 °C, ascribable the combustion of the residual organic component[11]. The grounded bone samples exhibit powder X-ray diffraction patterns characteristic of hydroxyapatite (Figure 8a). The coherent crystalline domains (τ_{hkl}) values, which are related to the crystal size and strain, were calculated from the full width at half maximum intensity (FWHM) using the Scherrer equation[12]:

$$\tau_{hkl} \quad \frac{k\lambda}{FWHM\cos\theta}$$

where λ is the wavelength, θ the diffraction angle and K a constant depending on crystal habit (chosen as 0.9). The values of FWHM and τ_{hkl} reported in Table 3 indicate a good degree of crystallinity for both kinds of bone. Accordingly, the infrared absorption spectra of both cortical and cancellous bone exhibit sharp phosphate absorption bands (Figure 8b). Other than the phosphate bands, the

TABLE 3
FULL-WIDTH HALF-MAXIMUM AND COHERENT LENGTHS (TH_{KL}) OF THE PERFECT CRYSTALLINE DOMAINS ALONG THE LONG AXIS (002) AND ALONG THE CROSS SECTION (310) OF THE CRYSTALS (STANDARD DEVIATIONS IN PARENTHESES), TOGETHER WITH CA/P MOLAR RATIO VALUES OF CORTICAL AND CANCELLOUS BONE

	FWHM (002)	τ (002)	FWHM (310)	τ (310)	Ca/P (molar ratio)	Ca/P (weight ratio)
Cortical bone	0.296(4)	276(4) Å	0.724(18)	117(3) Å	1.66	2.14
Cancellous bone	0.268(4)	304(5) Å	0.730(20)	116(3) Å	1.32	1.70

FTIR spectra display bands at 1455–1430 cm^{-1} and 870 cm^{-1} associated with the carbonate symmetric and out of plane stretching mode, respectively. The presence of carbonate is quite modest, and, according to the thermogravimetric results, accounts for about 2wt% both in cortical and in cancellous bone. The analytical values of Ca/P molar ratio for cortical and cancellous samples are reported in Table 3.

Discussion

The continuous layer of cortical bone on the left diaphysis in relation to the surface of detachment of the femoral neck and head, the concavity of the corresponding acetabular fragment (denoting normal development of the proximal epiphysis of the femur during growth; Figure 4) and the normal appearance of the contralateral structures exclude a congenital malformation. Therefore, the observed bony modifications can be attributed to damage incurred after the completion of skeletal development.

The described picture seems to refer to a trochanteric fracture not followed by consolidation (non-impacted fracture). Such a fracture could have produced two fragments (diaphysis and head-neck-part of lesser trochanter) or three fragments (diaphysis, head-neck, and part of lesser trochanter).The fracture seems very close to the capsule margin in its superior-anterior part, but extracapsular in its posterior-inferior part. It can thus be classified as a pertrochanteric fracture[13]. The continuous layer of cortical bone on the fracture surface of the distal fragment accounts for the non-union. The missing left femoral head and neck can be explained either by the fact that the proximal fragment (or fragments) underwent necrosis, which would have partially or completely destroyed it, or by loss due to taphonomic processes acting before exhumation of the skeleton. As expected given the chronology of the skeleton (first half of the 19th century), there are no signs of surgical intervention.

The macroscopic and radiographic appearance of the bones of MCP account for severe diffuse osteoporosis. The metrical data from CT examination confirm this visual impression (Tab. 2). This diagnosis is also consistent with the microscopic, chemical and structural analyses, while densitometric data, that seem in disagreement, require further interpretation.

The morphology of bone tissue damaged by osteoporosis has been clearly outlined by a series of light and electron microscopy studies. These studies showed that cortical bone thins with aging and osteoporosis, showing resorption on the endosteal surface and a progressive enlargement of the Havers canals with formation of progressively more porous tissue[14,15]. Cancellous bone tissue shows trabecular thinning and loss of continuity with the trabeculae surface presenting numerous Howship lacunae[16].

Morphological analyses of bone fragments from the pseudoarthrotic surface show the presence of a continuous thin layer of cortical bone, likely due to remodelling phenomena. Histological features compatible with osteoporosis are disclosed. The most significant histological changes in cortical bone architecture were thinning of cortical bone, widened osteon canals, disrupted lamellae and various tissue lacerations. Changes in cancellous bone morphology mainly involved thinning and discontinuity of the trabeculae, and wide bone marrow spaces. The skeleton of MCP was stored in damp conditions for a long time after her burial, and this may have fostered the *post mortem* degradation of bone tissue. This process has created lines of least resistance, partly explaining the appearance of the microlacerations and fracture lines observed and the loosed aspect of the bone lamellae. However, other features such as trabecular thinning and wide marrow spaces found in cancellous bone, endosteal resorption, widened osteon canals and oval microlacerations in cortical bone, and above all the many Howship lacunae, reflect an osteoporotic bone damage that occurred during life.

The results of thermogravimetric analysis indicate a higher inorganic phase content of cortical than cancellous bone, which is consistent with what is reported in the literature[17]. However, the organic phase content is quite low with respect to the average values found in fresh bone (about 30%)[18], which might be due to *post-mortem* diagenetic processes. The even lower content of organic matter recently reported for archeological bones exhumed from graves of the late Roman period[18] supports this hypothesis.

With respect to the patterns usually recorded from fresh bone, which show just a few poorly resolved peaks[19], those reported in Figure 8a exhibit a remarkably greater crystallinity. The FWHM of the 002 reflection was used by Olesiak et al.[19] as a measurement of the crystallinity index, which was found to increase with the geologic age of fossilized bone. The values of FWHM reported in Table 3 are much smaller than those reported for modern

bone, and even smaller than those reported for Pleistocene bone[19], in agreement with the significantly narrow X-ray diffraction peaks present in the patterns in Figure 8. The infrared absorption spectra reported in Figure 8b confirm the high degree of crystallinity of the bone samples, as suggested by the relatively high sharpness of the phosphate bands, in particular the 604 cm^{-1} phosphate band[20]. Moreover, both spectra show a relatively high area ratio 1030/1110 cm^{-1}, which has been suggested to be related to mineral maturity, corresponding to the transformation of a nonapatitic domain into apatitic ones[20]. It has been reported that the trabeculae in osteoporotic bone are thinner than those in normal bone, whereas the mineral/matrix ratio is significantly reduced, and the bone crystallinity increased, with consequent increased fragility of osteoporotic bone[21]. In the present case, the observed high mineral/matrix ratio, as well as the high mineral maturity suggested by the relatively high area ratio 1030/1110 cm^{-1}, could be ascribed to the diagenetic process, whereas the relatively very high degree of crystallinity could support the presence of osteoporosis problems. Osteoporosis in MCP finds a further confirmation in the values of Ca/P ratio. The Ca/P value determined for cortical bone is just a bit smaller than the mean values reported in the literature for human female cortical bone[22]. At variance, the value obtained for cancellous bone is significantly smaller than the average values reported in the literature for human female trabecular bone[23]. A significant difference in the mean Ca/P ratio between postmenopausal osteoporotic patients and premenopausal controls has been observed by a modified dual energy X-ray absorptiometry system[24]. Moreover, reduced Ca/P values have been obtained in osteoporotic bone with respect to age-matched normal bone, using synchrotron radiation microtomography[25].

The results of densitometric analysis are in agreement with the chemical and structural data, which, though in general consistent with a diagnosis of osteoporosis, revealed values of mineral/matrix ratio and mineral maturity higher than expected, most likely because of diagenetic processes. As a matter of fact, at variance with the comparison samples where the mean density generally decreases with age, as expected, MCP shows very high values (Tab. 2). The diagenetic processes, causing dissolution and reprecipitation of the bone mineral[26], as well as loss of the organic matrix[18], could also explain the overall quantity of minerals identifiable with densitometric techniques.

Despite the influence of post-mortem damage and diagenetic changes of the bones, the study of the skeleton of MCP allowed the diagnoses of a non-union pertrochanteric fracture not surgically treated in the left femur and of diffuse osteoporosis. Alterations of the preserved vertebral fragments suggest a picture of advanced degenerative arthritis common in aged individuals.

In postmenopausal osteoporotic women the most frequent types of fractures are vertebral, distal forearm (Colles fracture) and hip fractures[27]. The epidemiology of vertebral fractures is not well established as many of them escape clinical diagnosis[27]. Wrist fractures are the most common breakage in perimenopausal women and their incidence rises rapidly after the menopause, but reaches a plateau after about 65 years of age, probably because of age-related decreases in the speed and strength of extending the arm to protect the body during falls[27]. The incidence of hip fracture increases substantially with age, especially after 80 years of age[28]. Aitken[29] reports that in severely osteoporotic women trochanteric fractures occur twice as often as cervical fractures. It is thus possible that the femoral fracture of MCP was osteoporosis-related. The remodelling of the lesion suggests a long surviving period, likely several years, after the fracture occurred[30]. The preservation status of the vertebrae and forearm bones did not permit to assess the possible presence of fractures at these sites.

In modern clinical practice, besides surgical intervention (nail, screw), pertrochanteric or intertrochanteric fractures can be treated by traction and immobilisation[31–33]. Even in the case of conservative treatment non-union and avascular necrosis are very rare, and consolidation occurs after 45 to 75 days of immobilisation, depending on the degree of displacement[32,34]. During the first half of the 19th century the diagnosis of this type of fracture was difficult, even if the first descriptions of femoral neck fractures with differential diagnosis go back to the first half of the 18th century[35]. The treatment of these fractures was essentially based on reduction, traction, and immobilization of the leg with different types of immobilizers and extensor-apparatus. The results of these techniques were usually unsatisfactory and rarely lead to healing of the fracture, but more often they resulted in pseudoarthrosis and shortening of the leg[36]. The surgical treatment of this type of fractures became possible only in the second half of the 19th century, thanks to the introduction of anesthesia, asepsis and X-rays.

In our case, repair of the diaphyseal stump, and possibly necrosis of the proximal fragment(s), likely took many months, and most probable, the injured woman was able to resume some degree of movement and perhaps mobility with the help of crutches. Crutch use induces specific modifications of the joints and entheses[37–40]. Unfortunately, the poor preservation of the bones did not allow observation of the articulations and most of the entheses, in particular the possible asymmetry of their development. The generalized and (in the cases in which we could score both sides) strong bilateral development of the entheses reflects the advanced age of the subject[9,10]. However, the presence of enthesophytes at the femoral insertions of *mm. gluteus maximus* and *vastus medialis* only on the right side could be related to greater locomotor stress on the healthy limb. The higher thickness of the cortical bone of the right femoral shaft could also represent an adaptation to the greater load on this limb. These features suggest a long period of time, maybe several years, between the accident that caused the fracture and the death of MCP at 80 years of age.

Palaeopathological cases of trochanteric fractures have been reported[41–43], but are relatively rare due to the fact that they are typical of an age class rarely represen-

ted in osteoarchaeological samples[30]. A very interesting case refers to an osteoporotic female skeleton (>50 years old) from Lisht (Upper Egypt, XIIth Dynasty) showing a pertrochanteric fracture with non-union[44] similar to that of MCP. According to the authors, the proximal fragment underwent post-traumatic osteolysis, and the outer third of the femoral head is the only remnant. Also in this case the radiographic examination revealed thinner cortical bone in the fractured femur with respect to the contralateral one, probably due to the major involvement of the healthy limb in weight bearing after the occurrence of the fracture. The degree of remodelling at the fracture site and disuse atrophy suggested that several years must have elapsed between the fracture and death[44].

Conclusions

The anthropological study of human skeletal remains can be used to reconstruct the osteobiography of dead individuals. The palaeopathological investigation contributes to the general knowledge about diseases affecting the skeleton[45] and provides methodologies and information that may be useful for anthropologists engaged in the study of legal cases.

In the case described in this paper a non-union pertrochanteric fracture not surgically treated and probably due to senile osteoporosis has been diagnosed in the skeleton of an identified aged woman. The remodelling of the fracture surface, as well as the thinner cortical bone in the shaft of the affected femur and the asymmetry of lower limb entheseal changes, likely consequences of an altered locomotory pattern due to the fracture, suggest that the individual survived several years to the injury.

It must be pointed out that diagenetic changes affecting bone preservation, morphology and composition, can limit the diagnostic possibilities. In particular, regarding osteoporosis, our study underlines that in unearthed skeletons the cortical thickness, microscopic features, degree of crystallinity and Ca/P ratio could represent more useful indexes than the mean bone density, mineral/matrix ratio and mineral maturity, more sensible to taphonomic and diagenetic changes that affect *post-mortem* the mineral phase.

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Authors' Contributions

VM, MM and MGB performed the anthropological and palaeopathological study. VM and MM drafted the paper. EO, AlT and AR performed the microscopic study and wrote the respective part in the Methods, Results and Discussion sections. GF, SM and DC performed radiological and palaeopathological examination and wrote the respective part in the Results and Discussion sections. UA, SG, SD, AnT performed the CT analyses and wrote the respective part in the Methods and Results sections. EB, KR and AB performed the chemical and structural study and wrote the respective part in the Methods, Results and Discussion sections. VM assembled the various parts finalizing the overall article. MGB critically revised the paper and designed the research.

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OSTEOBIOGRAFIJA STRARIJE ŽENE IZ 19. STOLJEĆA SA PERTROHANTERIČNIM LOMOM I OSTEOPOROZOM: MULTIDISCIPLINARNI PRISTUP

S A Ž E T A K

U ovom radu iznosi se osteobiografija starije žene pronađene u grobnici na groblju gdje je bila pokopana 1850. godine. Istraživana su njena sveukupna antropološka obilježja. Kako bi se dobila iscrpna slika stanja skeleta provedena su makroskopska, rendgenska, tomografska, mikroskopska, i kemijska i strukturna ispitivanja. Dijagnosticiran je kirurški neliječen pertrohanterični lom, nastao vjerojatno uslijed senilne osteoporoze. Posljedice prijeloma pokazuju da je ta osoba vjerojatno živjela još nekoliko godina nakon ozljede. Opisane značajke kosti (kost na mjestu prijeloma, asimetrična promjena u entezama vjerojatno povezana sa iskrivljenim hodom) mogu biti korisne kod identifikacije kostura. Što se tiče detektiranja osteoporoze u iskopanih kostura, naša studija naglašava da su debljina korteksa, mikroskopske karakteristike, stupanj kristaličnosti te Ca/P odnos puno korisniji od srednje gustoće kostiju, omjera minerala i matrice te mineralne zrelosti, a koji su više osjetljiviji na diagenetske promjene koje post-mortem utječu na mineralnu fazu.