Seminars in
ULTRASOUND
CT and MRI

Role of Radiology in the Assessment of Skeletons from Archeological Sites

Marta Licata, PhD,* Adelaide Tosi,* Rosagemma Ciliberti, PhD,† Paola Badino,* and Antonio Pinto, MD, PhD‡

Radiology is an indispensable investigative tool for physical anthropologists and paleopathologists. Since its birth in 1895, X-ray has been useful in studying archeobiological finds. As a nondestructive technique of investigations, radiology allows for analysis of archeological finds without damaging them.

Radiological investigations in anthropology are very important to assist: (1) reconstruction of biological profile (age at death, sex, stature, and ethnicity; (2) diagnosis pathological conditions, and life style (diet, physical stress, etc.); (3) interpretation of postdepositional process (diagenetic or taphonomic factors).

We are sure that the importance of radiology in anthropology will continue to increase, and we confident that these disciplines will ultimately fuse and lead to the birth of a new professional branch of research: "Archeoradiology" or "Anthroradiology."

Semin Ultrasound CT MRI 40:12-17

Introduction

The use of radiology is certainly not overlooked by paleopathology and, more generally, by bioarcheology. In fact, the study of ancient bone remains, both in terms of anthropological and pathological investigation has always benefited from the use of radiology and from the techniques made available by the development of this discipline, starting from X-rays, Computer Tomography (CT) and 3-dimensional (3D) CT reconstruction, up to the use of magnetic resonance imaging (MRI).

Radiological analyses are used in osteoarcheology for anthropological investigations and pathologic analysis on ancient bones as these methods allow us to access many different areas, including hidden bone structures (eg. the endocranium, tooth roots, sinuses, and cavities of the long bones).

Among the medical-clinical methods applied to anthropology, radiology is the most appropriate approach to the study of ancient human remains because it can be used without causing any damage to the find.

In our experience, radiological investigations are mainly used to study traumas and other alterations found on the bone previously noticed at the macroscopic level.

"Digital anthropology", "paleoradiology" and "archeoradiology" are terms resulting from the need to reinforce a well-established relationship between historical and archeological disciplines and techniques of biomedical imaging. Today, in fact, archeology regularly interrogates radiology about the resolution of some anthropological and pathological issues, without damaging a find usually destined to musealization.[1]

In addition, radiological analysis allows for virtual reconstruction of human remains characterized by fragmentation, or just covered in organic sediments where removal would compromise the integrity of the specimen. In fact, on some fragmentary remains it is sometimes possible to create "virtual restorations" of the absent parts, based on the contralateral profiles or on the interpretation of the contiguous ones. In addition to this, it is evident that the possibility of virtually reconstructing the internal anatomical structures allows the integral use of the morphological information contained in

*Department of Biotechnology and Life Sciences, Centre of Research in Osteoarcheology and Paleopathology, University of Insubria, Varese, Italy.
†Department of Health Sciences, Section of Forensic Medicine and Bioethics, University of Genoa, Genoa, Italy.
‡Department of Radiology, CTO Hospital, Azienda Ospedaliera dei Colli, Naples, Italy.
Address reprint requests to Marta Licata, PhD, Department of Biotechnology and Life Sciences, Centre of Research in Osteoarcheology and Paleopathology, University of Insubria, O. Rossi, 9, 21100 Varese, Italy. E-mail: marta.licata@uninsubria.it

 https://doi.org/10.1053/j.sult.2018.10.003
0887-2171/

the finds and consequently the creation of molds faithful to the original that lend themselves perfectly to the didactic use and research. For example, the intracranial casts that had important scientific implications for the study of paleoneurology on prehistoric remains.

In recent years, another application of radiology appeared on the scientific scene and allowed the reconstruction of facial morphology. The result is equivalent to a simple approximation that has the purpose of re-evoking a detail, a clue that may suggest a suspicion of identity, especially in forensic archeology. In the historical-archeological context, the use of 3D reconstruction for human remains allowed us to reproduce the faces of men in the past, thus enriching museum collections. An exemplary case is that of Richard III whose skeletal remains were recovered in 2012 during an archeological campaign in an ancient Franciscan monastery (on the site of Greyfriars Church in Leicester, a Franciscan monastery built in the 13th century and destroyed in 1530). The place of discovery and the pathologic signs, including an evident curvature of the spine and some injuries to the skull and lower limbs, have suggested that this was the skeleton of the regent. The immediate examination of the DNA compared to that of the distant descendant of the sister, Michael Ibsem has shown that "beyond reasonable doubt it is Richard." The realization of a 3D plastic model was the result of a computerized study that added muscular and skin layers starting from the skull. It is evident that besides the pure digital anthropological reconstruction, it was possible to insert other elements thanks to the many iconographies that portray the famous monarch.

Radiological analyses in the study of osteoarcheological collections often allow us to better observe anthropological aspects such as: inclusion of artifacts, identificative traits (sex, age at death, stature, and bodily indices) and the most common pathological evidence such as traumatic injuries, occupational markers, degenerative stress, vitamin deficiencies, and signs of infection. Indeed, radiology can be really useful to analyze more rare pathological conditions that have left their mark on bone.[2] Other investigative advantages are those offered by conventional portable radiography. In fact, these tools can be transported to archeological sites, so it is possible to conduct radiographic analyses of the find without removing it from its context of discovery.

New paleoradiological approaches

Since 1999, in addition to the application of X-ray and CT, an advanced form of CT, called Multislice-CT (MSCT), has become available for clinical purposes. MSCT can be used in the anthropological identifications of human remains, both on the skeleton and on the teeth. In forensic anthropology, MSCT allows to perform a comparative identification, through the comparison of ante- and postmortem data. MSCT exams provide optimal results.

Generally, the decision to apply virtual reconstruction technique is prefixed according to the aims of the research and to what must be investigated. It is therefore possible to obtain 2-dimensional (2D) reconstructions, sagittal, coronal, and oblique or 3D, multipart reconstructions, maximum projection intensity and volume rendering technique.[3]

These radiological investigations can be applied in different contexts of our interest: exhumation contexts, museum researches, mass disasters, archeological burials and paleoanthropological sites.

The length of time for postprocessing analysis united to the number of scanners available today represent limits to the application of MSCT technique.

Today, other radiological techniques are applied regularly to anthropology. Multidetector CT (MDCT), dual energy CT (DECT), micro-CT, magnetic resonance imaging, and digital volume tomography (DVT) are highly advanced techniques. In particular, MDCT is advantageous because it removes overlapping of the structures and allows us to discriminate various densities. MDCT offers the possibility to observe the spatial relations of the portions to be investigated, to select an area of interest and to measure the density of the structures.[2] Data can be reprogrammed on any display plane and 3D reconstructions can be obtained. It is evident that 3D reconstructions allow us to observe some pathological lesions difficult to recognize, such as calcified lymph nodes.

Using Micro-CT on the other hand allows us to obtain detailed information on smaller objects.

Lastly, DVT is a small CT scanner that creates high-resolution 3D images of the head and neck and is generally applied to investigate certain diseases of the head. In addition, the DVT also allows to obtain detailed images of distal ends such as hands and feet.[2]

Identification analysis

Radiographic reproduction of the skeletal remains is a prefect tool to observe an archeobiological find without damaging the artifacts. Beyond that, the observation of anatomical features useful for the anthropological investigation could be enhanced through the radiological investigation.

In the generic identification, bone remains are studied to determine the biological profile, whose most important characteristics are: age at death, sex, stature, and ethnicity.

Age at death can be determined by examining the dental arches and the bones. Radiology allows a better analysis of biological age. Well known by anthropologists is that skeletal and dental age are not always related to chronological or official age and are subjected to interindividual variations. It is important to consider that there is indeed a statistical correlation between a person's chronological age and its growth and biological senescence. It is possible to estimate the age at death of an individual from direct observation of the skeleton. Evaluation of biological age is usually more accurate in the early stages of development and its accuracy is reduced in adult subjects.[3] From gestational to adolescent age many methods are based on the analysis of bone growth: ossification centers, degree of eruption of teeth, and the length of diaphyseal bones.

Radiology can assist in the estimation of age at death of a child for example, applying an X-ray approach on dental arches to observe the formation of teeth in the gum so therefore to associate it with age. As mentioned above also from the length of the diaphysis it is possible to correlate an estimate of age. In this regard, it is interesting to report the study on fetal age conducted by a group of Portuguese researchers. This research proposed the creation of regression tables and equations for a Portuguese population based on the measurements of the diaphysis's length (femur, tibia, and humerus) recovered from postmortem radiological images of 100 known gestational age fetuses. The researchers recorded an important connection concerning the longitudinal length of the examined bone and the gestational age; the femur shows the strongest correlation (r= 0.969; p= 0.000), the tibia (r= 0.966; p= 0.000) and the humerus (r= 0.963; p= 0.000). In this way, it was possible to obtain the regression formulas and tables with reference values for each district bone.[4]

It is interesting to note that some anthropometric methods that are useful for determining age at death of ancient skeletons are calibrated on samples of contemporary populations, therefore clinical radiograms.

To estimate age at death of adult individuals, anthropologists observe the degree of senescence of some joints, in particular of those not exposed to biomechanical stress (pubic symphysis, auric surface of the ileum, and sternal extremity of the fourth rib).

Radiological investigations allow us to even better underline the degenerative changes at the surface level on the articular surface which regularly change the surface shape: ilium auricular surface, pubic symphysis, and sternal rib.

The diagnosis of sex is very complicated at a macroscopic level in children as they have not yet reached skeletal maturity and do not show the typical dimorphic traits of the skeleton. However, it is necessary to highlight that females generally show an advanced skeletal maturation compared to males.

In bioarcheology, sex can be investigated through a morphological and morphometric analysis of the skeleton. The most dimorphic districts are the skull and the pelvis. 3D reconstructions offer the possibility to enhance the observation of the dimorphic elements and to cut virtually the bone; this last operation is not possible macroscopically as it is mostly findings are rare samples such as hominid fossils or mummies. From an anthropological point of view, the macroscopic analysis finalized to diagnose sex observes: the forehead, the general shape of the skull, the mastoid process, the mandibular branch, and the shape of the pelvis bones, especially the greater sciatic notch. Radiology can assist in the determination of sex in adult skeletons as it allows for better observation of dimorphic traits of the skull (glabella, orbital margin, maxillary, mastoid process, plan nuchal, etc.) and on the pelvis (concavity sottopubic, sciatic notch, branch ischio-publico, iliac crest, etc.) (Fig. 1).

In addition, the "radiometric" analyses aimed the identification of sex by the measurements of some epiphyses such as the diameter of the head of the femur and of the humerus.

In this regard, we report the study of a sample of adult skeletons aimed at sex determination. In particular, the method is elaborated using radiographs of the proximal epiphysis of the femur obtained from 2 samples of skeletal remains (a total of 70) exhumed in St. Konstantinos and Pateles Cemeteries, Heraklion, Crete. The first one comprised of individuals born in Crete between 1867 and 1956 while the second comprised of individuals who died between 1968 and 1998. The proximal epiphysis of the entire collection was examined with a digital machine X-ray (TCA 4R PLUS). By comparing the macroscopic and radiological measurements, the radiographic technique has shown to be better than the conventional methods of physical anthropology. The use of metric methods applying radiology makes it possible to diagnose sex and can also be used in forensic cases.[5]

Figure 1 3D computed tomography (CT) reconstruction of a skull showing male dimorphic traits from archeological site of Sarigo (Varese), Church of St. George.

The radiological measurements of the skeleton allow us to obtain precise morphometric analysis. To proceed with estimation of stature, body proportions, body indexes and craniometrics. To estimate the stature, the mathematical method is based on the correlation between bones and body parts and height by using multiple regression formulas elaborated by anthropologists from several skeletal collections.

The anthropometric analyses allow to determine the cranial indices and defines the cranial forms: brachiocranium, mesocranium and dolichocranium, the shapes of the orbits, the nose and the degree of prognathism of the face. It is also possible to determine the degree of robustness of an individual starting from the metric investigations. In fact, the degree of strength of the individual limbs can be determined from the relationship between the transversal and sagittal diameters of the various long bones. At this point, it is interesting to report the study conducted by Croatian researchers who have evaluated four radiomorphometric indices of mandibular bones from a skeletal sample discovered in the Crypt of Požega Cathedral in Croatia, dated to the 18th century. The morphometric data obtained was related to age, sex, diet, and pathology and they revealed that they were equivalent to those registered for the present populations of northern Croatia regions.[6]

It is evident that morphometric data can define also the ethnicity of individuals. In determining the ethnicity of a population, that is the phenotypic features, the skull is essential.

In this regard, it is interesting to report the study conducted on the morph volumetric features of the neurocranium in the population of Campania in the last 2700 years. The authors have made the comparison between a contemporary and an ancient skull collection, discovered in the ancient Etruscan necropolis of Pompei and Pontecagnano and dating back to the 6th-5th century BC. The analysis on the skulls were carried out with MDCT, which is extremely reliable in the identification of craniometric points and in the measurement of linear and angular indices, thanks to the use of multiplanar and 3D reconstructions. This allowed us to highlight some interesting elements, including one where the neurocranium, over time, increased its overall capacity following brain growth. The study made it possible to understand the quality of the methodology compared to the conventional cephalometric analysis as it allows reproducible linear and angular measurements to be obtained.[7]

Paleopathological investigation

Radiographic technology found space in the paleopathological analysis to add detail to interpretations of certain pathological diagnoses.[8]

With radiological investigations, it is possible to analyze several pathological conditions such as: traumas, infectious diseases, tumors, etc.[9-10] In this review article, we report only the most frequent pathological conditions easily observable in osteoarcheological sample.

Traumas

In particular, for traumas, CT investigations are essential to understand the time (antemortem, perimortem, and postmortem) and localization of the injury, and classify documented wounds into blunt, sharp, and projectile force traumas.

Among the cases studied by our research center lesions were discovered so it was necessary to use computerized axial tomography to clarify the extent of the lesions.

The first case radio-analyzed was discovered inside a church of ancient medieval foundation, in Biumo Inferiore, Varese. The skeleton, dating back to 11th-13th centuries, belongs to a man whose age at death was estimated to be about 60 years and the height around 180-185cm. The skeleton macroscopically shows an interesting lesion on the cranium. At the level of the upper left orbital margin, a fracture (2.4cm long) is completely resolved. It is believed to represent a sharp force trauma. The result is in fact an elongated fracture with sharp margins and formation of bone callus on the right edge that spreads along the entire margin of the wound. The lesion, oblique and on the left portion of the frontal, may be indicative of a blow from the top by a right-handed person. The macroscopic observation was integrated by the axial volumetric acquisition and by following the 2D coronal and sagittal reconstructions and ray-sum reconstructions at the Radiology division of the Gaetano and Piera Borghi Foundation of Brebbia (VA). The analyses have allowed us to highlight the fracture which we classified as "surface fracture."[11]

Other interesting pieces of anthropological datum come from another necropolis that have been studied by our research group: the ancient cemetery area of Saint Agostine in Caravate, dated between the 8th and 9th century AD. In particular, several skeletons exhibit antemortem lesions at the cranial level. Among the most interesting cases is that of tomb 1. It is the skeleton of a woman whose age at death was estimated between 40 and 50 years and the height of about 150cm. The skull presents a small quadrangular perforation at the front right of the skull, perhaps caused by a pointed weapon with a pyramidal head. Radiological investigations allowed us to observe bone remodeling that confirmed that the wound was not fatal.

Signs of traumatic injury were found on the lower limbs and on the skull from tomb 2. In particular, on the left fibula is the presence of bone callus formed as a result of a fracture, while, on the left side of the skull, there is a fracture of 1cm in diameter, probably associated with a blow caused by a blunt object. In addition, the skull has some particular "scratches" (maximum length 4cm) at the level of the frontal bone, both on the left and on the right. From our first observation it was thought that these violent claw-like injuries were caused by an object with sharp and very thin beaks. Given the complexity of the case, we have intervened with the CT study carried out with axial volumetric scanning and 2D and 3D ray-sum reconstruction. The examination clarified the sub-millimeter depth of the lesions, which therefore affected only the external bone. Because of the subtlety of the lesions, the possibility of a relationship between these signs and the diagenetic factors that sometimes alter the bone surface of the skeleton has been hypothesized, that is postmortem scars caused by the intervention of roots and their acidic spills, together with water being trapped between the root and the bone, can leave footprints on the outside deck. Instead, following several comparisons in literature we hypothesized them to be vascular imprints.[12-13] Another case of our osteological collection was discovered in the cemetery area of San Biagio (Cittiglio, Varese). The skeleton belongs to a young man, age approximately 30, 170cm tall. The skull of the individual shows 3 important perimortem sharp force injuries which are localized on the parietal and occipital bones. Radiological analysis allowed us to understand that the time of the injury was near to that of the death.[14] Among cases study in our center of research we observed several cases of antemortem blunt traumas, for example from the tomb 31 of Sarigo which presents an important lesion at the right parietal bone (Fig. 2).

An interesting case of trauma is represented by the study carried out on the skeletal collection of the cemetery of the

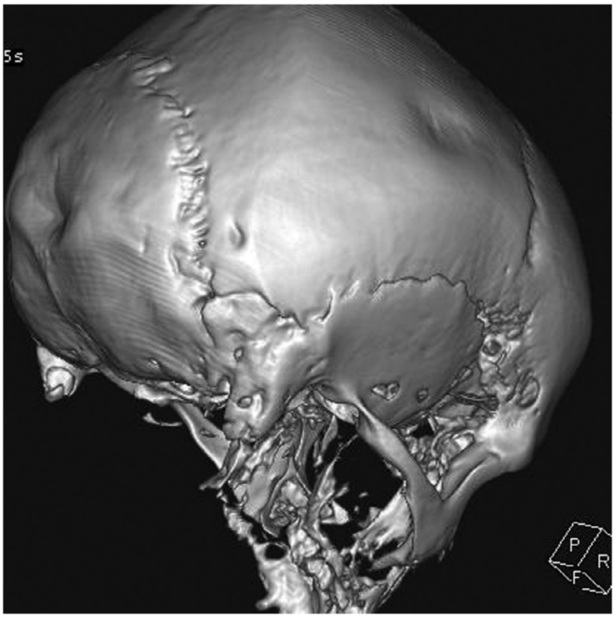

Figure 2 3D computed tomography (CT) reconstruction of a skull from the tomb 31, (Sarigo, Church of St. George, Varese) showing an ante mortem blunt force trauma at the right parietal bone.

Meerenberg psychiatric hospital in Bloemendaal, in the Netherlands, dating back to 1891-1936. The article presents 4 paleopathological cases of osteomalacia, where radiological investigations were performed in suspected cases since the radiological counterpart of pseudofractures is considered pathognomic for osteomalacia. In this study, radiology was useful to demonstrate suspected pseudofractures.[15]

In addition to conventional radiology methods, MSCT is also applied to the paleopathological examination of lesions. Bone is an excellent indicator of the type of trauma. Knowledge of the type of fracture can define the nature of the injury or the injuring agent. A study on lesions performed with MSCT is of interest because the original images and the virtual reconstructions of the specimens are of high quality. By comparing the perimortem lesion bone density measurements to these images it is possible to obtain a better evaluation of the etiology. At this point, it is interesting to point out a study carried out on 3 skulls showing surgical trepanation from archeological burials located in the Altai Mountains and dating back to the 5th-3rd centuries BC. The classical macroscopical analysis on the finds was integrated with the MSCT. The MSCT allowed us to clarify the cause of trepanation, in particular in the skull that belonged to a female it was possible to observe an injury located in the right temporal bone, probably the result of a falling from height, and to establish that it was the reason of the surgical intervention.[16]

Generally, degenerative pathologies are best observed in osteoarcheological collections that are arthrosis manifestations especially observable at the level of the vertebral column. Recent epidemiologic studies show a close relationship between the arthritic manifestations and the lifestyle of ancient populations and it is, however, evident that, together with enteropathies and traumas, the anatomical outcomes of arthropathies also represent the most important skeletal indicators of occupational activities. This disease has principally 2 types of development, proliferative and erosive, but in osteoarcheological research, it is sometimes difficult to diagnose the latter, as postmortem digenetic factors can simulate this pathology. Instead, the proliferative arthritic development, in which osteogenesis alters the normal profile of the vertebrae, is more recognizable in archeological contexts (Fig. 3). Schmorl's nodes (Fig. 4) are generally found in osteoarcheological material but the effect of this disease on the quality of life (pain, mobility, etc.) is not clear. Thanks to the radiological investigation we managed to characterize with precision the osteophytic formations and degenerative lesions.[17]

Among the cases studied in our center, the radiological report on a medieval skeleton from the church of Vedano Olona made it possible to highlight a fairly severe arthritic condition. Bone structure in the regular complex, well preserved, without evident signs of pathology in addition to the widespread arthrosic framework. From radiological investigation it was possible to observe the cervical spine: spondyloarthrosis, with irregularity limiting the somatic of the vertebral bodies, marginal osteophytosis, uncoartrosis; widespread interapophyseal arthrosis; reduced the C3-C4 and C6-C7 disc space. In the dorsal spine: coarse spondylosis in the middle dorsal site with bulky presence of marginal osteophytes and reduction of the amplitude of the disc spaces; less pronounced spondylosic signs in the other dorsal traits; presence of coarse Schmörl's nodule are limited on the caudal of the vertebrae of D9. Finally, in the lumbar spine: spondylodiscartrosis presents osteophytosis and reduction of the disc spaces; interapophyseal arthritis. Apparent fusion between L4 and L5 supported by extensive "bridge" calcification of the intervertebral ligaments, with preserved amplitude disc space and an absence of alterations.

Also some infectious diseases, important in history, have already been investigated by anthropologists with the aid of radiology. The study carried out on a Roman skeleton dated between the second and third century AD has highlighted a strong suspicion of treponematosis. The skeleton, male, aged 25-30 years, recovered in the archeological site of San Nicasi in the northeastern region of the Iberian Peninsula, had a saber-shaped left tibia. Radiological examination of the tibia

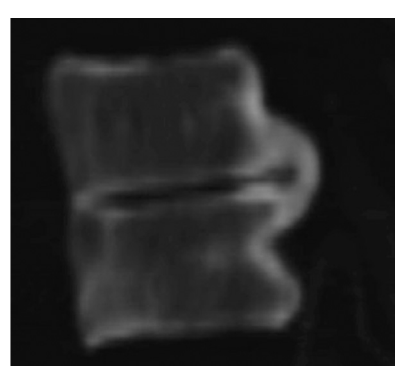

Figure 3 Computed tomography (CT) scan of vertebrae with evident bone bridge (Crypt of Azzio,Varese).

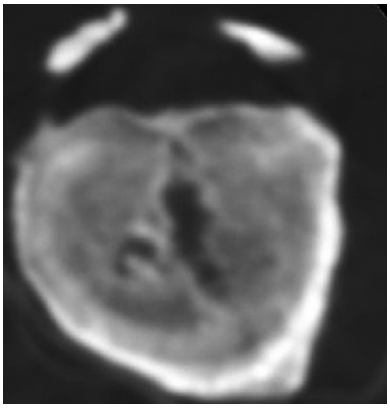

Figure 4 Radiography of vertebra with a Schmorl's node (Crypt of Azzio, Varese).

cross-section revealed the involvement in the medullary cavity of cancellous bone and loss of cortex. Using CT, the observed lesions indicated that the tibia was suffering from a chronic infectious disease. The successive differential diagnosis also considered fibrous dysplasia, Paget's disease, chronic varicose ulcers and, finally, the diagnosis of treponematosis was made.[18]

An example of how much radiology can help in discovering pathologic conditions that cannot be observed at the macroscopic level, in our experience, was evident in the skull of the tomb 1 of Caravate. After the first radiological investigations to clarify the skull lesion, CT unexpectedly revealed compact, dense and uniform areas of thickening. The clear edges, a radiolucent peripheral rim located in the right sphenoid sinus and some ethmoidal cells in the rear left petrous apex allowed us to see some osteomas. It is difficult to contradict radiology diagnoses of craniofacial osteoma presented as dense and compact clumps consistent with clean edges and radio transparent rims. Therefore, the osteomas diagnosis is clear. Osteomas are benign neoplasms characterized by slow growth that clinically affects cranial and long bones, and histologically display the proliferation of either compact or cancellous bones. It may occur in endosteal or periosteal surfaces, with considerable size variations. Osteomas develop mainly in the head and in the neck regions, which includes the facial bones, skull and mandible, and are the most common benign tumor of the sinonasal tract. The location of osteomas in the occipital region is extremely rare. The osteoma is not asymptomatic, since it can alter sinus drainage and deform the walls of the orbits and protrude under the oral mucus.[19]

Conclusion

The use of radiological investigations in osteoarcheological experiences will continue to increase and will certainly have a significant relapse in archeological research.

The possibility offered by radiology to thoroughly investigate the osteoarcheological findings without damaging them and reproducing them in 3D visualizations will also guarantee greater communication and knowledge of the anthropological find to the community.

References

1. Licata M, Borgo M, Armocida G, et al: New paleoradiological investigations of ancient human remains from North West Lombardy archaeological excavations. Skel Radiol 45:323-331, 2016
2. Beckett RG: Paleoimaging: A review of applications and challenges. Forensic Sci Med Pathol 10:423-436, 2014
3. Dedouit F, Savall F, Mokrane FZ, et al: Virtual anthropology and forensic identification using multidetector CT. Br J Radiol 87:20130468, 2014
4. Carneiro C, Curate F, Borralho P, et al: Radiographic fetal osteometry: Approach on age estimation for the Portuguese population. Forensic Sci Int 231:397, 2013
5. Kranioti EF, Vorniotakis N, Galiatsou C, et al: Sex identification and software development using digital femoral head radiographs. Forensic Sci Int 189:113, 2009
6. Ivanišević Malčić A, Matijević J, Vodanović M, et al: Radiomorphometric indices of mandibular bones in an 18th century population. Arch Oral Biol 60:730-737, 2015
7. Cappabianca S, Perillo L, Esposito V, et al: A computed tomography-based comparative cephalometric analysis of the Italian craniofacial pattern through 2,700 years. Radiol Med 118:276-290, 2013
8. Rossetti C, Pasquinelli L, Verzeletti A, et al: A case of Paget from a Northern Italy medieval necropolis. Int J Paleopathol 20:104-107, 2018
9. Kacki S, Velemínský P, Lynnerup N, et al: Rich table but short life: Diffuse idiopathic skeletal hyperostosis in Danish astronomer Tycho Brahe (1546-1601) and its possible consequences. PLoS One 13:e0195920, 2018
10. Gawlikowska-Sroka A, Szczurowski J, Kwiatkowska B, et al: Concha bullosa in paleoanthropological material. Adv Exp Med Biol 2016. https://doi.org/10.1007/5584_2016_161
11. Licata M, Ronga M, Cherubino P, et al: Different types of traumatic lesions on mediaeval skeletons from archaeological sites in Varese (North Italy): Diagnosis on ante mortal fractures using macroscopic, radiological and CT analysis. Injury 45:457-459, 2014
12. Licata M, Armocida G: Trauma to the scull: an analysis of injuries in ancient skeletons from North West Lombardy archaeological sites. Acta Med Hist Adriat 13:251-264, 2015
13. Licata M, Vecchio I, Armocida G: Analysis of ante-mortem injuries in medieval skeletons from the necropolis of Caravate (Varese) Italy. Acta Med Mediterr 30:555-559, 2014
14. Licata M, Rossetti C: Osteoarchaeological evidence of an unknown medieval battle in Northern Italy. A case of Forensic Anthropology. J Forensic Leg Med 51:74-75, 2017
15. Van der Merwe AE, Veselkab B, Van Veen HA: Four possible cases of osteomalacia: The value of a multidisciplinary diagnostic approach. Int J Paleopathol 2018. https://doi.org/10.1016/j.ijpp.2018.03.004
16. Krivoshapkin AL, Chikisheva TA, Zubova AV: Trepanations in the population of the Altai Mountains in the Vth - IIIrd centuries B. C Zh Vopr Neirokhir Im N N Burdenko 78:62-71, 2014
17. Licata M, Armocida G, Broggini M, et al: To investigate the degenerative alterations of the spine in Paleopathology. Acta Reumatol Porto 42:94-95, 2017
18. Rissech C, Roberts C, Tomás−Batlle X: A Roman Skeleton with Possible Treponematosis in the North−East of the Iberian Peninsula: A Morphological and Radiological Study. Int J Osteoarchaeol 23:651-663, 2013
19. Licata M, Borgo M, Armocida G: Diagnosis of multiple osteomas in an ancient skeleton discovered in the necropolis of Caravate - Northern Italy. Eur J Oncol 21:238-242, 2016