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Forensic anthropology: developments of a classical discipline in the new millennium

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Abstract

The present brief review is a survey of the role of forensic anthropology (FA) in the new millennium. After an introduction which deals with the expanding definition of the discipline and the issue of professionality and training, the author approaches the role and novel developments of the field, with particular reference to the past 5 years. Such developments are discussed in a sectorial manner, distinguishing the role of research in the areas of forensic anthropology which deal with human remains and those that deal with the living. As regards the ''human remains'' domain, advances and stalls still present in the fields of species and postmortem interval determination, sexing, aging and attribution of ancestry are stressed. The need for standards in facial reconstruction and positive identification by bone morphology are underlined, as well as the growing role of the anthropologist in detecting signs of trauma. Finally, the relatively new role of the forensic anthropologist in the domain of identification of the living is described, although this area is still underrepresented as regards research activity: these studies concern the strive to devise methods for identifying faces (e.g. in the case of crimes registered by videosurveillance systems), aging living individuals or juveniles represented in pedopornographic material.

Keywords: Forensic anthropology; Identification; Species; Sexing; Aging; Ancestry; PMI; Trauma; Osteology

1. Forensic anthropology in Europe

In order to discuss the issue of new developments and research in forensic anthropology (FA), it is important to establish what exactly is meant by ''forensic anthropology''. Unfortunately the term still brings to mind sliding calipers and osteometric boards—a scenario which should be considered too restricted in this day and age. Regardless of who is to adopt anthropological procedures on human remains of forensic interest (a pathologist, an anthropologist, a biologist) it must be accepted that forensic anthropology is, just like forensic pathology, an increasing and multidisciplinary field. One could go as far as to say that it is the field which works in parallel with forensic pathology as far as human remains are concerned. In other words, just like the pathologist deals with the human cadaver from the scene of crime to establishing time and cause of death, in the same manner the anthropologist, when nothing remains of a victim but bones, must deal with the search and proper retrieval of the skeleton (using subdisciplines such as forensic archaeology) and with issues such as identification and detection of signs of trauma which may lead to establish cause and manner of death. However, not only is this discipline involved in the study of the dead, but, more and more, anthropological expertises are requested in the identification and aging of living individuals. All this has seen in the past few years specialists applying notions of anthropology and associated disciplines to aging juvenile perpetrators, identifying bank robbers taped on videosurveillance systems and establishing whether presumed victims of pedopornography are under age.

Since forensic anthropology has as its definition ''the application of physical anthropology to the forensic context'', it is obvious that the field is requested to deal with a spectrum of issues which extends from osteology to human physiognomy, keeping in mind the fact that the field is becoming more and more multidisciplinary and that collaboration with other specialists is in fact crucial.

In the acceptance of this larger definition of the discipline one main cultural obstacle must be overcome: who is the forensic anthropologist [1]? There still seems to be, in many

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countries, a distinct division between experts who work in the forensic scenario, namely forensic pathologists, and those who work in the anthropological context, mainly anthropologists working on archaeological material. Let us take the example of human remains. The scientific and forensic community have come to realise that there is a void when human remains are found in the forensic scenario: most forensic pathologists do not have an anthropological and osteological formation, whereas classical anthropologists may not be used to working with human remains still bearing some soft tissue or found in a modern criminal context. Physical anthropologists have always been, if we set aside ethnographists, cultural anthropologists and geneticists who work on human variation (and even here the fields sometimes blend into one another), considered as experts in human osteology. Thus, the anthropologist's contribution to anything coming from the forensic scenario ''traditionally'' deals with aging, sexing, determination of ancestry or race, stature, etc.; in other words, anything similar to what the anthropologist's task is when studying skeletal remains of ancient populations. However, traditional anthropology is not enough for the forensic context. Forensic anthropologists must deal with identification and cause of death. Forensic Anthropology, as a forensic science, cannot be compared to forensic odontology, toxicology, botany or entomology. These last examples all have to do with a very restricted aspect of the body or body parts, or with biological phenomena related to other sciences more in general. The anthropologist and pathologist both have to deal with the human body in toto: the more soft tissue on it, the more it is the domain of the pathologist, the more skeletonized, decomposed or burnt, the more it is the domain of the anthropologist.

The area of interest increases even more if we look at the newer applications of forensic anthropology, for example, the identification of the living. Judging the similarity of two faces and detecting the characters leading to positive identification which will scientifically hold in court may be considered a typically anthropological task—however, very few physical anthropologists are trained in the study of physiognomy.

So, who is the forensic anthropologist, both from a professional and ''research'' point of view ? Particularly across Europe, this is a very delicate issue and it may concern experience and training more so than specific academic qualifications, at least at the moment. In anglo-saxon countries, namely the US and the UK, the forensic anthropologist falls into a defined category, i.e. that of he or she who practices FA, this being ''the application of physical anthropology to the forensic context'' [2,3]. In the United States, the discipline is more organized at least as far as training is concerned, while in Europe the problem still remains unscathed. Across Europe, training is very dishomogeneous, and the quality of such training cannot be ascertained. This is certainly an issue to solve. It is very difficult to perform a cross-country analysis of the status of forensic anthropology and anthropologists in Europe, as regards professionalism, training, type of work, as has been done for the US. Only recently have people who work in the field across Europe started discussing, comparing notes and approaching the issue. Thus, only recently, has the need for the constitution of a European association where these types of questions are discussed and solved appeared. Hence, the main goals of the recently formed Forensic Anthropology Society of Europe (FASE), a subsection of the International Academy of Legal Medicine, are education, harmonisation and certification, along with the promotion of research. The profile and training of forensic anthropologists in Europe has to be defined in detail. Taking into account that the reality is different from one country to another and that the issue of unidentified cadavers and human remains is almost unknown a call for forensic anthropology in Europe and other developing countries is mandatory [4,5].

Regardless of the issues concerned with qualifications and training in this relatively new and still disoriented field, the following summary cannot be an exhaustive review of all applications and research being performed, but has as its goal to illustrate how the field is changing, what the current areas of application are and what is new in research, particularly in the first years of the new millennium.

1.1. Modern roles of forensic anthropology in forensic medicine and development in research

The following is a brief summary of developing applications of forensic anthropology and related research in its two main fields of interest: the study of human remains and identification of the living.

1.1.1. The study of human remains

The main role of forensic anthropology, traditionally, has been in the study of human remains, and in particular, in identification. Not only is forensic anthropology applied to single cases; the usefulness of forensic anthropology has been documented in the study of war crime victims and in mass disasters. Several authors have already underlined the importance of forensic anthropology in recovery and identification in Kosovo, stressing the problems related to the lack of antemortem data [6–8]. More rare, although extremely useful, is the contribution of forensic anthropology in mass disasters when severe fragmentation, burning or commingling has occurred, as in the case of the World Trade Centre disaster [9].

Furthermore, the role of forensic anthropology in building detailed biological profiles is extremely useful in tackling the issue of single cases of unidentified human remains across Europe—a problem which still has to be solved due to the lack of national and international databases [4]. Therefore, although the scope of this brief article concerns applications and research, the social and ethical role of the anthropologist in helping to create networks for the identification of human remains should always be kept in mind.

1.1.1.1. Search and recovery of human remains. Not infrequently anthropologists are involved in the retrieval of or, to a lesser extent, the search for human remains. In the latter case, it is evident that the role of the forensic anthropologist is minor, although he or she must be aware of techniques available for performing a proper search for buried human remains. The

difficulty of detecting the burial site is obvious, particularly if years have gone by or if the area is very woody. Methodological tools such as field walking, aerial photography and other archaeological methods are reknown, although research in the area has recently given interesting inputs concerning the use of cadaver dogs [10], of sophisticated techniques such as ground penetrating radar [11] and even the division of field portable analytical instruments which use decompositional odor analysis via a chemical sensor in order to detect human remains buried in shallow graves.

However, it is at ''scenes of crime'' where human remains have to be retrieved that forensic anthropology becomes the crucial tool. Physical anthropologists are key personnel in the case of skeletonized or partly-skeletonized remains, badly charred bodies and buried bodies. In the case of quasi-skeletal, skeletal or charred remains found on the ''surface'', the person appointed to observe, register, recover and generally ''take care'' of the remains must have experience in osteology. Lack of such experience may lead to serious errors such as non-retrieval of skeletonized remains scattered across the surface by fauna. In order to recover the entire skeleton, it is necessary to be able to quickly perform an inventory of all human bones and know how to identify them. Numerous times body parts which are at or near the scene of crime are not collected because of such lack of preparation. In particular, when dealing with non-adult skeletal remains, very small bone pieces can be misidentified or simply not recognized at all by non-experts. This implies loss of information. Similar or even more difficult problems are encountered in the case of charred bodies where the specialist has to retrieve all body parts scattered in a car, for example, among other debris. In the case of buried remains, these must be exhumed and collected with stratigraphical and archaeological strategies. Although this is an applicative field in which actual research is improbable, publication of case reports [12] stressing the risks and benefits of anthropological and archaeological methods at the scene of crime should be encouraged. Retrieval and registration of remains without archaeological methodology will lead to loss of body parts, loss of stratigraphical information useful for determining the postmortem interval, damage to bones which will in turn lead to difficulties in interpreting bone trauma, for example.

1.1.1.2. Species identification—is it human?. When small fragments of bone are found, it is sometimes not evident even to expert anthropologists whether they are human or not particularly in cases of badly burnt bones, of fragmented diaphyseal shafts and of cranial bones of very small animals. In these cases more specific tests must be performed. The advent of DNA analysis has certainly slowed down other investigative techniques and research in this area, such as protein analysis or the study of the microscopic structure of bone-all useful tools in verifying whether the fragment is human or not. Such confidence in DNA may be dangerous. In many instances, for example, with charred or very dry bone, DNA cannot be extracted. Thus, protein analysis or the study of the microscopic structure of the fragment may be useful, and, at times, the only applicable method. However, research in this area is relatively scarce and has stopped at the late 1990s [13]. Few exceptions exist: Ubelaker et al. [14], picking up from previous immunological studies on species-specific protein detection in old and ancient bone, recently developed an RIA to identify species origin of bone, whereas Mulhern and Ubelaker [15], following the theory that bone microscopic morphology may be species specific, have studied the differences in osteon banding between human and non-human bone. More research, however, should be performed in both areas. It is known that proteins are more resistant than DNA to many environmental factors and thus methods for detection of species-specific protein in bone should be encouraged, such as immuno-PCR, a technique which amplifies the sensitivity of immunological ELISA tests by tagging a DNA marker to one of the ELISA reagents and subsequently performing PCR. Furthermore, there is much more to be learned on the microstructure of bone and its potential for species specificity, for example, on flat and subadult bones.

1.1.1.3. Postmortem interval (PMI) and taphonomy. The older human remains are, the more difficult it is to estimate the postmortem interval (PMI). Once the remains reach the morgue or the laboratory, the pathologist is left with entomological methods, if soft tissue and larvae are present, and very little else for determining PMI. The anthropologist, if it is the case of dry bone, can only express an opinion on whether the bone looks archaeological, old or recent, but nothing more. Time since death is indeed one of the more difficult questions to be answered by the forensic anthropologist due to the virtual absence of methods by which to evaluate the PMI. Sometimes it is impossible to say whether it is a case from past populations or a forensic case. The problem is that there are no accurate methods for quantifying PMI, making it virtually impossible, many times, to differentiate between 15 or 50 years, for example, which has obvious important implications for legal procedures.

In the past, Yoshino et al. [16] examined the postmortem changes in human compact bone using microradiography, electron microscopy and microscopic spectrophotometry (to reveal UV-fluorescence). They suggested that skeletonization of a buried body occurs around 5 years after deposition and that histological changes of compact bones generally begin around the same time frame. Using UV-fluorescence analysis they provided regression equations for the calculation of time since death. Luminol testing has also been performed to evaluate the possibility of assessing PMI from bone tissue. This method is based on the reaction of luminol with blood residues. The intensity of the chemiluminescence was analysed to assess its relationship with time since death. The results suggested a correlation between intensity and time since death, but as the authors stated the technique should be tested on a wider sample with the aim of performing a statistical test and evaluating its statistical significance [17]. Clearly, macroscopic and microscopic methods or methods looking for soft tissue residues cannot be considered reliable since they are dependant on an enormous amount of extrinsic and intrinsic variables.

Regarding the aid of chemistry in dating human remains, Vass et al. [18] carried out research on the concentration of volatile fatty acids, cations and anions in the soil solution under a decomposing corpse. The concentration of volatile fatty acids (VFA) was analysed when dealing with soft tissue decomposition while the concentration of anions and cations was measured when the corpse was skeletonized. Concentrations were then correlated to ''accumulated degree days'' (ADD). Authors stated that it is possible to estimate time since death by VFA ratios, a description of the corpse and the environmental temperature. Moreover, the study shows that ions extracted from the soil solution can yield valuable information concerning PMI of skeletonized human remains [18].

A useful tool to evaluate the forensic or anthropological interest of a body, may be the method suggested by Ubelaker [19]. This method benefits from the high levels of artificially introduced carbon-14 in terrestrial organisms by thermonuclear devices between 1950 and 1963. The study is based on the observation that different tissues of the body have a diverse time of development and a diverse turnover. Quantifying radiocarbon values in different tissues and placing these values in the bomb-curve, taking care of noting the age of the individual and other factors, allows an estimation of the date of death.

Thus, in conclusion, research performed in the past few years has focused on (a) seasonal effects of decomposition [20,21] up to skeletonization; (b) observation of macroscopic features of bone (Verhoff et al. [22] verified the presence of features which they never found present in bones less than 50 years old); (c) the aid of other sciences, such as forensic botany and marine zoology [23,24]. However, if we consider the skeleton per se, the only chance of determining PMI from bone is with chemical methods which are now being studied, such as radionuclides and trace elements [25] or artificial radiocarbon [19].

1.1.1.4. Building the biological profile. One of the most ancient areas of interest for the forensic anthropologist is the determination of age, sex, race, stature, pathologies and other anomalies, in order to create a biological profile, or, in other words to generate the osteobiography.

In this specific area research seems, in a somewhat repetitive fashion, to have focused on validation of old methods on different populations.

As far as sexing is concerned, there is still a great prevalence of articles dealing with sexual dimorphism detectable on different bones of skeletal populations, for example, the patella, the tibia and the foramen magnum [26–28]. One interesting study has evaluated observer differences in using typical sexing methods such as Phenice's triad [29].

The issue of aging both adults and subadults has even more articles dedicated to it. Once again, literature shows the proliferation of articles which apply known macroscopic and microscopic techniques on cranial sutures [30,31], auricular surfaces [32] and the acetabulum [33]. Other authors have focused on the utility of combining age indicators as opposed to using a single method [34]. However, aging does remain a large gamble and much confusion still exists as to accuracy, precision and error of different methods tested on different populations, usually with different statistical parameters. Finally research on amino acid racemisation persists, not only on teeth but also on bone [35]. Although this method seems to be the most promising because of its small range of error, many researchers have commented on the difficulty of interlaboratory reproducibility of the same technique.

Stature estimation still collects publications and once again measurements and metrics of tibiae, femurs and sacral and coccygeal vertebrae (more interesting) of different populations is still frequently the object of major publications [36–38]. Similar comments can be made for race, although in this field more research certainly needs to be done. Interesting studies have been performed on racial variability concerning the mandible [39], pelvis [40], teeth [41], cranial non-metric traits [42], cervical spinous processes [43], and femur [44] which indeed aid in the difficult diagnosis of ancestry attribution of human remains.

In conclusion, particularly as regards sexing, aging and stature estimation, a future goal for the anthropological community should be to create working groups in order to coordinate all research which applies traditional methods on different populations, so that results may be pooled and published in a homogeneous and coherent fashion.

1.1.1.5. Cranio-facial reconstruction. This technique, preferably referred to as facial approximation, which can be performed manually or with computer softwares, should be used only to stimulate the memory of the public in order to reach a suspicion of identity.

The past 5 years have seen a considerable proliferation of witty and useful articles which strive to verify the value of facial approximation and try to make it more accurate. Stephan and Henneberg [45] and Stephan [46,47] have published interesting data concerning the reliability of forensic anthropology and the frequent lack of relationship between facial approximation and resemblance ratings. Furthermore, they found that not necessarily are facial reconstructions bearing a resemblance those which are identified as the specific person. De Greef and Willems [48] have focused on the potential of computer-aided facial reconstructions whereas several bits of interesting research have been performed concerning anatomical guidelines for more accurate reconstructions of the eye [46,47] and the mouth [49,50], for example. The field requires more research of this sort, although stronger connections with the cognitive sciences should be sought for the achievement of more accurate reconstructions since much still has to be learnt on what actually triggers recognition in the human brain.

1.1.1.6. Other personal descriptors. The disciplines of osteology and in particular palaeopathology supply a plethora of information on how to extrapolate disease, stress markers or simple anatomical anomalies, such as non-metric traits, from human remains, which could be incredibly useful for building the biological profile. Unfortunately, very little research has been done recently on the potential of palaeopathological characters in identification (apart from a study performed by

Devriendt et al. [51] on hyperostosis frontalia)—this field should be encouraged.

1.1.1.7. Positive identification of human remains. Once the construction of an identikit or biological profile, eventually with facial reconstruction, of a victim has led to a suspicion of identity, positive identification must be performed. This is usually left to geneticists, fingerprint experts or odontologists. However, at times, bone morphology may come in handy.

In order to identify a person it is possible to compare the shape of bones, just as though each bone were a fingerprint, even if these methods are not standardized. It is clear that the comparison, as always, must be carried out between antemortem and postmortem radiographs of different skeletal districts. Consequently if antemortem radiographs of the various osseous districts (for example, head, thorax, limbs, abdomen, etc.) are available, it will be possible to compare the morphology of the skeletal elements visible on the radiograph with the same osseous elements belonging to the human remains (both working on the actual osseous elements, and on their radiographs).

Apart from exceptional morphological peculiarities (osteophytes, bone calluses, etc.), the difficulty consists in determining which and how many are the morphological elements sufficient for a definite identification. The literature tells us that personal identification in this way is carried out by means of a meticulous comparison of details. However, a minimum number of points does not exist – as exists instead for fingerprints – in order to carry out identification. Usually it is intended that one to four characters, without evident discrepancies, are considered sufficient for identification. The problem is that an agreement does not exist yet on what exactly is meant by a significant character. It is clear that the areas compared must be scarcely modifiable in time. However, the peculiarity of the character and the consistency between the antemortem and postmortem shape is left, in part, to a subjective evaluation and to the experience of the operator.

Recent literature has considerably developed the potential of FA in positive identification. Kuehn et al. [52] have shown that a morphological approach in identifying remains via bony peculiarities visible on chest X-rays can be very useful. Similar studies have been performed on frontal sinuses [53,54], foot and ankle X-rays [55] and hand X-rays [56], with particular reference to the Daubert guidelines of scientific validity. Single identification procedures with bony details on CT scans [57] have also been reported as well as with cranial suture patterns [58]. In this last case also particular attention to Daubert criteria was given. These pieces of research are a valid indication of how identification by bone morphology should strive towards some sort of standardisation in order to be accepted in court, just like genetic testing.

A final comment should be spent on cranio-facial superimposition. Recently some authors have hailed its utility [59] although great caution should be taken. This method should be used only for excluding identity if gross incompatibilities are present.

1.1.1.8. Trauma analysis—determination of cause and manner of death. Trauma analysis, once again, is a major area of interest for forensic anthropology. In general, whenever bone traumatic injuries are found, the presence of a FA should be mandatory. He/she should always give his statement on the distinction between antemortem, perimortem and postmortem origin and type of lesion.

Fortunately trauma research in forensic anthropology has started to flourish. Interesting studies have been performed showing the utility of macroscopic and particularly scanning electron microscopic studies on sharp force trauma inflicted on bone [60,61], although Bartelink et al. [62] in a very well planned study demonstrate how difficult reconducting a cutmark to a specific tool may be since there is a large overlap in cutmark width between different knife types. As regards blunt force injury, Love and Symes [63] have provided information on the biomechanics behind rib buckle fractures. Finally, Pope and Smith [64] have provided an in depth study on interpretation of trauma on burnt bone by documenting in an experimental fashion the survivability and features of traumatic injury on burnt cranial bone. Further studies also have been performed on heat induced changes which are crucial for the interpretation of bone fractures [65]. Thus, research in the area of trauma analysis is beginning to give extremely important information.

However, very little is seen on the interpretation and diagnosis of antemortem versus perimortem versus postmortem fractures. The diagnosis of the vitality of a wound (whether it has been produced antemortem or postmortem) as well as determination of the time elapsed between the production of the wound and death (in other words the age of the lesion) is a crucial issue in forensic pathology. Due to the inflammatory reaction which follows wound production, when dealing with a well preserved cadaver, such issues seem fairly straightforward. In fresh skin, the red-purplish coloration (haemorrhagic infiltration) of a cut or bruise will reveal its vitality, and therefore antemortem formation, whereas the change in coloration, from a macroscopic perspective (from blue to brown to yellow, etc.) will reveal the time of survival. In more difficult cases (e.g. when haemorrhagic infiltration is not so evident or when a more accurate time of survival is needed) microscopic analyses can be performed. Similar statements can be said concerning bone trauma, in particular fractures. Bone follows similar ‘‘laws’’ as concerns the evolution of the histological picture. Apparently, recent studies have also shed light on the utility of osseous apposition rates observed by toluidine blue staining in solving the ‘‘survival time’’ issue [66]. Furthermore, the beginning of healing processes, such as periosteal bone production (woven bone) and callus formation can be detected both macroscopically, once bone is cleared of soft tissue, and radiologically. However, these processes require a long time.

In the specific case of bone macroscopic appearance, the only study which correlates aspects of new bone formation and survival time is one performed by Sledzik and Kelley, remained unpublished [67]. Forensic anthropological literature stresses how the macroscopic appearance of bone fractures can only allow us to perform a diagnosis of ‘‘perimortality’’ (and not give a specific ante or postmortem date) when no new bone is visible,

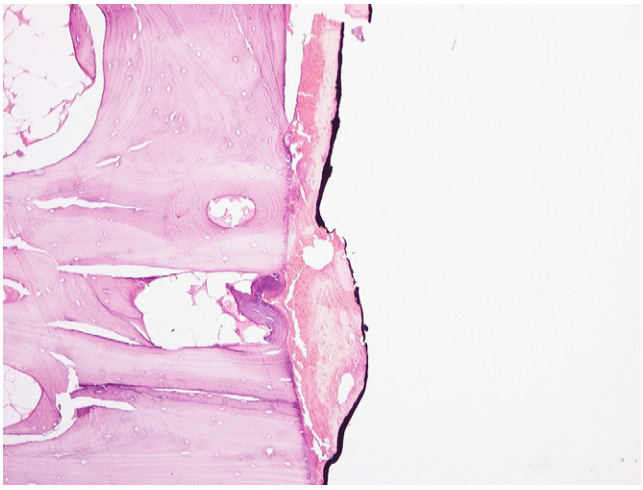

Fig. 1. A pilot study performed in our labs has shown that histological signs of haemorrhaging can be detected even on recent dry bone [83]. The picture shows an H&E section of a bone fracture produced in vivo (after a car accident) 14 days before death. The bone was taken at autopsy, macerated until all soft tissue had disappeared. Histological analysis of the fracture margin showed the persistence of soft tissue signs of vitality of the wound. The lighter color inside the blood clot is suggestive of fibrin deposits. Note the adhesion of the central part of the clot to the bone and the thin lines of fragmentation of the clot due to technical embedding artifacts above the area of adhesion to the bone. "Dry" bone may still give crucial information if histopathological methods are applied.

and of an antemortem origin only when woven bone appears, which according to these authors, is not before 10–14 days.

No in depth study however has ever been performed in order to verify, when working on cadavers and skeletal remains, the applicability of a histopathological approach to dry bone in the diagnosis of vitality and survival time. The barriers between histopathology and forensic anthropology sometimes can hinder very useful applications. Further research in this area is certainly mandatory (Fig. 1).

1.1.2. The study of the living

Forensic anthropology is showing its growing potential also with the issue of identifying living individuals, age determination and pedopornography.

1.1.2.1. Identifying the living. More and more cases see anthropologists involved in the identification of the living. These are frequently cases in which two-dimensional images from videosurveillance systems (showing robberies, assaults, etc.) are the only element available for identifying a suspect. This is a completely different aspect of forensic anthropology, which deals with human diversity and strives to verify morphological and metric characteristics which make the physiognomy of one person distinct from that of another.

Much research has been done on determination of stature and the study of gait and stride [68–70]. In the study of stature in particular great attention must be taken in order to verify distortion by projective geometry, i.e. by measuring the dimensions of real objects present at the scene of crime [71]. An even more difficult task is facial recognition. Classical literature refers to facial characters and indices (i.e. conventional anthropometry) in order to verify the resemblance between two individuals [72]. However, the dangers in comparing faces on two-dimensional images is too well known: slight, imperceptible differences in orientation, facial expression as well as interobserver differences in setting cranial landmarks may cause drastic errors in the study of indices. More novel methods strive to project a 3D model of the person under examination (produced with a laser scanner or with two stereoscopic cameras) on the 2D image of the person to identify, in order to check matching of facial landmarks and contours [73–76] (Fig. 2). This is indeed a very rich area of research and facial identification methods may, once finely tuned, change the scenario of surveillance

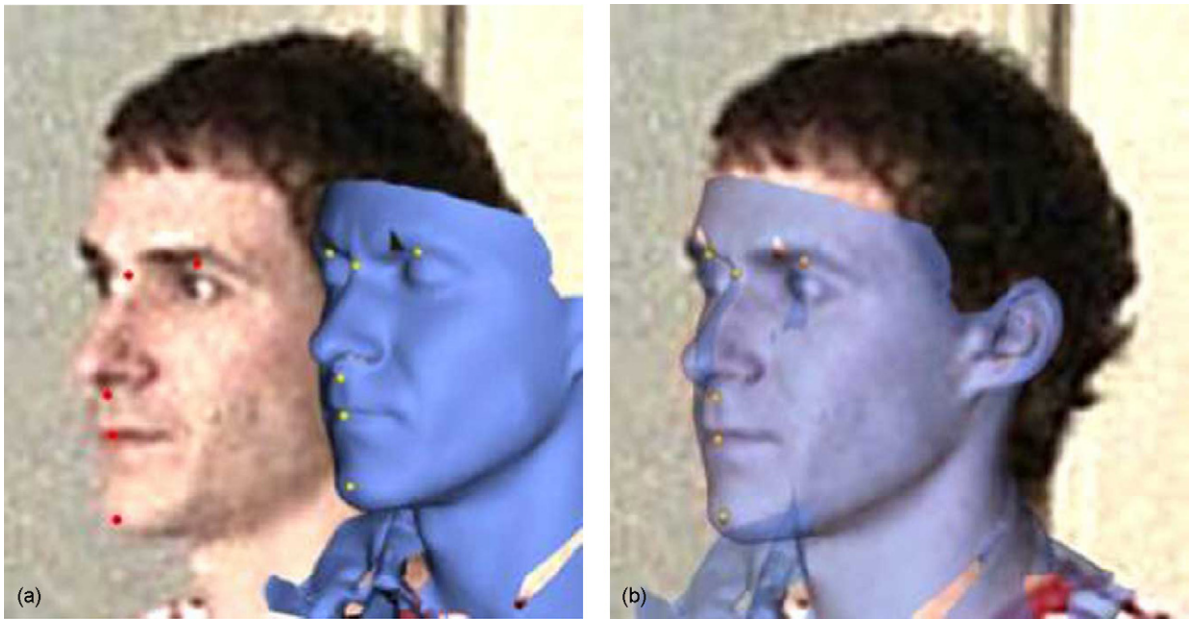

Fig. 2. (a and b) To the left one can appreciate the face of the perpetrator with next to it the 3D image produced with a laser scanner from the suspect. To the right, superimposition of the face and 3D model, to check for matching points and profiles [76].

systems and destiny of terroristic attacks, bank robberies and other crimes.

1.1.2.2. Determining the age of individuals for reasons of imputability. This is the case of living subjects with no identification documents. Frequently they are arrested and declare to be underage. Anthropological, radiological and odontological assessment is required for determining the probability that they are over or underage (14, 18, 21, depending on crime and country). Although this issue concerns radiology, auxology and pediatrics, it comes into the realm of anthropology also since it deals with a classical anthropological domain such as aging. Furthermore, the issue of ancestry should be taken into account, since geographical provenance may affect growth rates: thus, estimating the age of an African with methods which have been standardised on northern European populations may be a further source of error in final interpretation of age.

The greatest authority in the matter, Schmeling, has recently stressed the recommendations of the Study Group on Forensic Age Diagnostics, which declare that in order to determine the age of living subjects the assessment should include a physical examination, X-ray of the hand and wrist, dental examination, and an orthopantomogram. CT examination of the collar bones should be performed if the person is at least 18 years old [77].

1.1.2.3. Determining the age of subadults in photographic material (pedopornography). Once again, two-dimensional pornographic images can be the object of medico-legal/anthropological assessment. According to the country and legislation involved, the question frequently asked is the age of the child or adolescent (if, for example, under 10, 14, 16 or 18 years). This is a novel and very difficult aspect of age estimation, since facial and secondary sexual characteristics are extremely variable and do not necessarily represent chronological age [78]. Since the late 1990s in fact authors have cautioned against the misuse of standard puberty stages, such as the Tanner ones, to estimate chronologic age [79]. And more and more scientific articles are stressing the differences in sexual maturation rates within different geographical areas [80,81]. Pathologists, anthropologists, pediatricians and gynecologists are really left with very little in order to fight juvenile pornography. In this sense, recent research in Europe is oriented towards the study of facial parameters [82], but is only at the beginning.

In conclusion, this brief survey of the recent applications of anthropology suggests that not only forensic anthropology is establishing sound research in well-known areas, but it is also spreading its wings towards new and fascinating fields.

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