1 The Study of Ancient Bone Remains

Carla Caldarini, Paola Catalano, Valentina Gazzaniga, Silvia Marinozzi, and Federica Zavaroni

1.1 Funerary Archaeology and Field Anthropology

Carla Caldarini, Paola Catalano, and Federica Zavaroni

Bio-archaeological studies and historical documents are a great tool to reconstruct the lifestyle and health conditions of the ancient populations, and to understand the correlation between man and the environment over the course of time. The Anthropological Service has taken part in the environmental protection activity of the Soprintendenza Speciale per il Colosseo, il Museo Nazionale Romano e l'Area Archeologica di Roma. This has contributed to outline the biological history of Roman society, in particular that of the Imperial age. In the last decades, new excavation methods applied to the human skeletal remains have helped to collect valuable information on Roman sepulchres, especially those found in the Suburb, because of the large number of civil buildings built after the urban development. These data, together with those deriving from in-depth laboratory investigation, are helping to understand the complex biological landscape of the ancient Roman population with its bio demographic and social processes.

What did the Suburb look like during the Imperial age? As Rodolfo Lanciani [1] wrote: "In its best days, Rome was practically one with the nearby towns of Veii, *Nomentum*, Tivoli, Palestrina, Tusculum and *Bovillae*. Villas, vineyards, rural estates with country houses shaped both small and large areas creating a wide populated park around Rome".

In recent years, the investigation on a large number of broad excavations held by the Soprintendenza, has been throwing light on wide areas whose countless archaeological contribution had been ignored [2]. The anthropological material, firstly collected during the systematic excavation of the necropolis [3] and then through laboratory investigation [4] is a considerable help to understand how the funeral services were held and how life was in the Urbs and in its surroundings, in an attempt to analyse funeral customs and everyday lifestyle through a chronological and socio-historical perspective which has been overlooked for a long time [5].

Moreover, an inter-disciplinary analysis allows to establish a connection between the everyday life conditions, the diseases, and the specific therapies of the communities that the anthropological finds belonged to. This book is an example of the valuable contribution given by medical historians and pathologists to this aim.

The anthropological analysis of a burial must begin "in the field", at the time when it is found (Fig. 1.1). Taphonomy is the branch of knowledge which studies the processes (chemical, physical and biotic) that the body experiences between the individual's death and the body's discovery, based on the reconstruction of the action and interaction of the different factors which have interfered with it, from the moment of the deposition until its finding.

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Fig. 1.1 Burial during excavation

The information obtained through the taphonomic study of skeleton, reported case by case on an appropriate database, need a careful examination of the position of every skeletal element and the record of the condition of every joint. This is how the deposition can be defined as primary or secondary. In a primary deposition, the body has been buried, immediately after its death, in its ultimate place, where it decayed; at the time of unearthing, the skeleton must be in its original burial position, accepting for changes of position due to the action of taphonomic agents or secondary handling. Further changes of positions after the burial can be detected, whether designed, as in profanation, or accidental, linked to natural causes, as either the passage of animals or water damage [6]. A secondary deposition refers to a burial performed at two or more different times: the finding of the skeleton, and so the definitive deposition, happens in a different place from the one of the decay. The bones may have moved from their earlier position simply due to gravity, which pulls the bones down during the decomposition of the corpse, because of the absence of the soft tissues and ligaments which normally hold them together.

These movements can therefore be interpreted in order to reconstruct the original position of the body, thus highlighting the funerary practices of deposition: for instance, we will be able to determine the presence of perishable funeral structures (as cushions, coffins or dressings), or whether the deposition occurred in the ground, and so the decomposition took place in a restricted space, or in a sarcophagus, with the decomposition in a hollow space.

During the excavation process, experts should not only collect taphonomic information, but also determine, when possible, the gender and age at death of the subject, detect any pathological alterations and perform some measurements, because the frequent frailty of the finds can cause a serious loss of information, if the findings are recorded after the exhumation. This is the reason why most of the methods which will be briefly described below are usually applied in the field first and then in a laboratory in a more thorough and detailed way [7].

1.1.1 Determination of Sex

The parts of the skeleton showing features with the highest degree of sexual dimorphism are the skull (Fig. 1.2a, b) and the pelvis (Fig. 1.3a, b); in particular, the latter is structured in women to cope with pregnancy and birth giving. Because a subject rarely shows all the typical features of its gender, we have considered a combination of

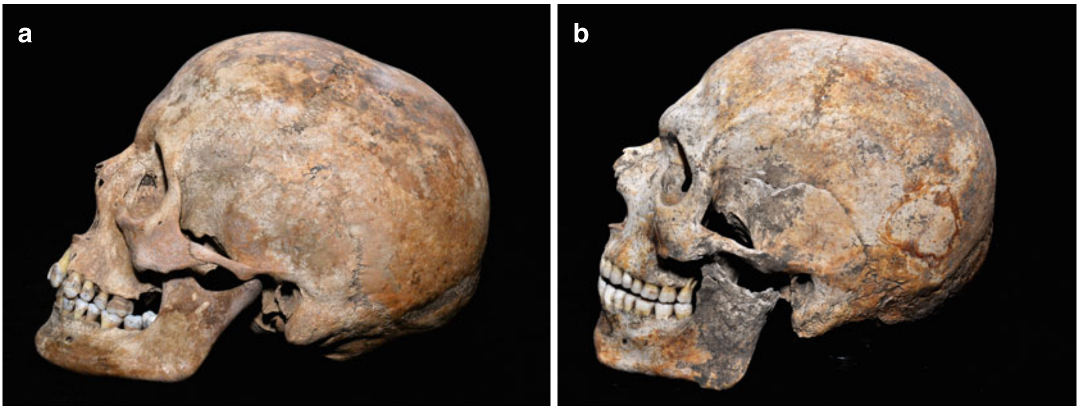

Fig. 1.2 (**a**) Female skull. (**b**) Male skull

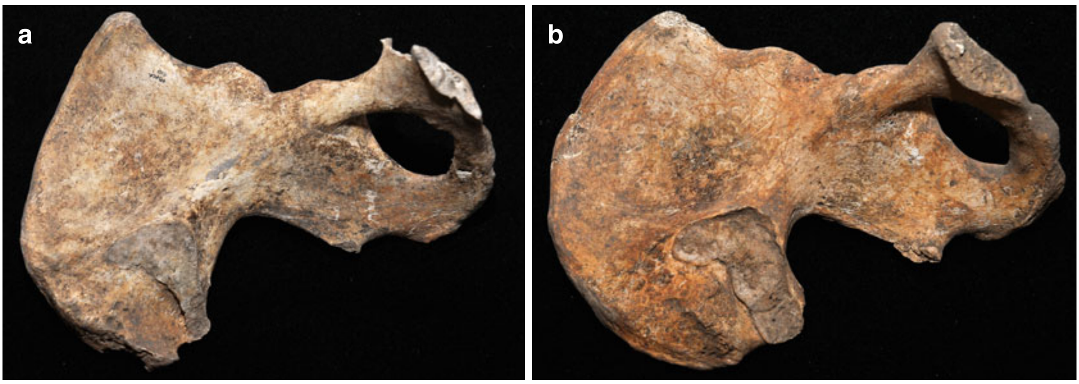

Fig. 1.3 (**a**) Female coxal bone. (**b**) Male coxal bone

features, taking into account their importance in the diagnosis, as described by various authors [8–11]. For some subjects, a gender diagnosis is sometimes impossible, because the findings are fragmented and incomplete.

1.1.2 Estimation of Age at Death

Various methods are used to calculate the age of death in adults, considering individual variability. The skeleton of an adult does not suffer great changes over time, so the age cannot be determined through the analysis of a single criterion; therefore, it is estimated applying several different methods and balancing the various findings, thus obtaining a time range in which the age of the subject under study is likely to be found.

One of the most noteworthy methods commonly used is the study of the degree of tooth wear, because the occlusal surface of the teeth gets thinner with age (Fig. 1.4a, b). Other factors determine tooth wear: the diet, the presence of dental-alveolus pathologies and some jobs involving the use of teeth [12].

The degree of welding of the ectocranial sutures has also been detected, based on the progressive fusion of the cranial sutures, until a complete obliteration, generally occurring in older age (Fig. 1.5a, b). Amongst all, Meindl and Lovejoy's method was used [13]. Then the auricular surface of the ileum was examined: in young subjects, the auricular surface is characterized by wavelet and diagonal rifts and the bone tissue is granular; with ageing, the diagonal rifts and the scratches decrease, the grainy quality of the bone

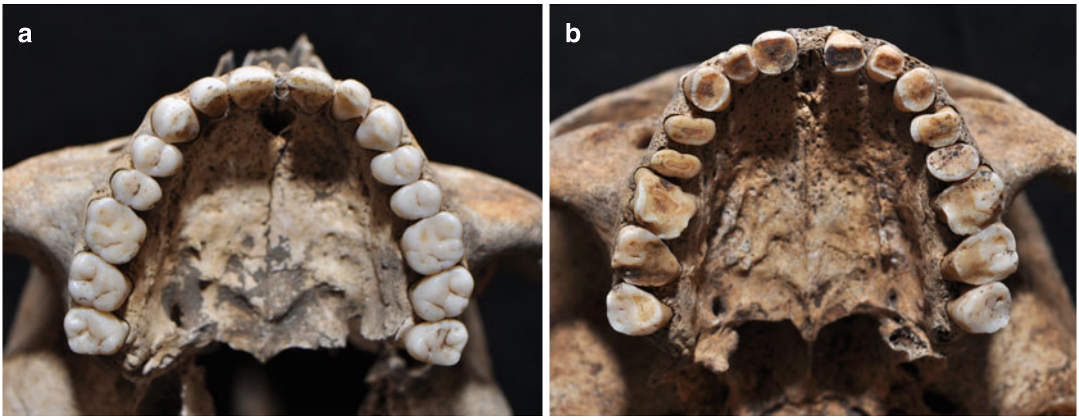

Fig. 1.4 (**a**) Mild dental wear. (**b**) Severe dental wear

Fig. 1.5 (**a**) Non-ossified ectocranial sutures. (**b**) Ossified ectocranial sutures

tissue is gradually replaced by small areas of dense and compact tissue and by porous portions, the margins becoming irregular and torn. In old age, the surface shows porous and eroded areas, the margins are irregular and in the retro-auricular area strong bone protrusions and osteophytes can be observed. Amongst all we used Lovejoy et al.'s method [14].

Moreover, the morphology of the pubic symphysis has been detected – in young subjects it is wrinkled, while with ageing it becomes irregular, with porosities, erosions and ossifications. We used Burns' method [15]. Then, the sternal end of the ribs has been examined – under 15 years of age the surface is flat and mildly wavy; with ageing it alters until it assumes a V shape, while the margins rise. After 55 years of age, the degenerative process prevails, until the margins fray and the porosity increases. Iscan et al. [16] studied these phenomena, but the method is difficult to apply due to the extreme frailty of the ribs.

The diagnosis of sub-adult's age at death (less than 20-year-old dead subjects) has been determined by the examination of the degree of development and dental eruption: this method identifies the different development phases and the dental eruption, an almost constant feature up to 14–16 years of age. We have used Ubelaker's chronology of dental eruption [17]. In addition, we have detected the size of the diaphyses of the long bones, and compared the values obtained with some charts based on the tight connection between the length of the long bones (measured without epiphyses) and the subject's age. However, it is important to bear in mind that measurements are always affected by the individual and population variability [18]. Considering the degree of ossification of the growth cartilage, we can estimate the subject's age if it is less than 24 years: in most cases, at this age the diaphysis and epiphysis of the bones, which compose the skeleton, are completely fused. In this study we used the standards given by Krogman e Iscan [19], France e Horn [20], Suchey et al. [21], Ubelaker [18], Iscan [22].

Fig. 1.6 Femur measurement with an osteometric board

1.1.3 Osteometry

All the bones which were intact enough to be measured were analysed osteometrically in a laboratory, in order to evaluate the length, width, section and circumference. We followed Martin and Saller's measurement procedure [23]. For every measurement we have indicated Martin's number and the commonly used abbreviation. The measurements are expressed in millimetres (mm) and taken with appropriate anthropometric instruments, such as the osteometric board (Fig. 1.6), the round curved compass to measure width and length, the digital calibre to measure sections and the millimetre strip to measure the circumference.

We used the osteometric dimensions to elaborate the height [24, 25] and the main indices of strength and section of the long bones, to try to highlight morphometric differences due to dynamic and environmental factors, such as stress from physical exercise or nutritional deficiency.

The main indices are as follows:

1.1.3.1 Cranial Indices

Cephalic index (horizontal) (8/1 × 100): ratio between width and maximum length. This determines the elongated (*dolichocranium*) or short (*brachycranium*) shape of the skull.

Height index (vertical-longitudinal) (17/1 × 100): ratio between the height measured at the bregma and the maximum length. This determines the degree of flatness of the cranial vault.

Frontal transverse index (9/10 × 100): ratio between the minimum and maximum frontal diameter. This determines more or less the diverging shape of the superior forehead.

Fronto-parietal index (9/8 × 100): ratio between the minimum and maximum frontal width.

Gnathic index (alveolar) (40/5 × 100): ratio between the length of the face and the nasion-basion length. This determines the degree of face prognathism.

Orbital index (52/51 × 100): ratio between the height and length of the orbit. This determines more or less a circular shape of the orbit.

Nasal index (54/55 × 100): ratio between width and height of the nose. This determines a longer or shorter shape of the piriform aperture (long and narrow: leptorrhine; short and large: camerrhine or platyrrhine).

1.1.3.2 Post-cranial Indices

Strength index of the clavicle (6/1 × 100): ratio between the circumference measured in the mid-diaphysis and maximum length.

Humerus diaphysic index (6/5 × 100): ratio between the minimum and maximum diameter measured in the mid-diaphysis. When the value of the index is close to 100 the two diameters are equal and the diaphysis is round shaped (euribrachy): when the minimum diameter is considerably smaller than the maximum, we have a flatness of the humerus (platibrachya), maybe caused by intense workload of the biceps and deltoid muscle.

Humerus strength index (7/1 × 100): ratio between minimum circumference and maximum length.

Radius diaphyseal index (5/4 × 100): ratio between the sagittal and transverse diameter measured in mid-diaphysis. The smaller the values, the more protruding the interosseus crest due to greater pronation and supination movements of the forearm.

Ulna olenyc index (13/14 × 100): ratio between the superior transversal and the superior dorsovolar diameters; this shows the transversal flatness in the superior section of the ulna.

Ulna diaphyseal index (11/12 × 100): ratio between the dorso-volar and the transversal diameters; the smaller the values, the more protruding the interosseous crest.

Ulna strength index (3/1 × 100): ratio between minimum circumference and maximum length.

Femur pillar index (6/7 × 100): ratio between the antero-posterior and transverse diameters, measured at mid- diaphysis. A high index means a strong development of the *linea aspera* (pilaster), often linked to thigh muscular work.

Femur platimetric index (10/9 × 100): ratio between the antero-posterior and transverse diameters measured below the lesser trochanter. An index lower than 85 means the antero-posterior crushing of the diaphysis superior third (platimery) generally linked to a strong development of the trochanters due to a great biomechanical stress.

Femur strength index ((6 + 7)/2 × 100): ratio between the sum of the antero-posterior and transverse diameters and the physiological length. A value higher than 12.5 means a good strength of the lower limb.

Tibia diaphyseal index (9/8 × 100): ratio between the sagittal and transversal diameters measured at mid- diaphysis.

Tibia knemic index (9a/8a × 100): ratio between the sagittal and transversal diameter measured at the nourishing passage. A value lower than 65 indicates the diaphysis flattening in a medio-lateral direction (platicnemia); the crushing is generally due to the work of the calf muscles, maybe due to a prolonged and intense use of the legs.

1.1.4 Dento-alveolar Diseases

The anthropological study has also covered the state of the dento-alveolar complex. The study of the oral pathologies is really important in anthropology because of the great amount of information that can be obtained; from the conditions of the teeth, we can obtain data on the eating and hygiene habits of the subjects. Any presence of tartar, dental decay, abscesses, parodontopathies and *intra-vitam* losses has been recorded.

Tartar, made of limestone deposits due to plaque mineralization, has been quantified in three degrees: small, average and large amount.

Dental decay easily develops when saliva is slightly acidic. Organic acids derive from carbohydrate fermentation due to bacteria in the plaque. If acidity is high, especially in a sugar-rich diet, it can break down the tooth mineral, and lead to enamel and dentin perforation. Dental decay is classified depending on location (occlusal, buccal, lingual, mesial, distal), severity (superficial, affecting the dentin, perforation or affecting the crown) and affected tooth area (crown, neck, root).

An abscess is caused by an inflammation reaching the tooth canal through decay, wear and tear or fracture. A tooth abscess can be detected through a drainage canal at the root apex. Also in this case we have recorded presence and position (buccal, lingual, apical).

Parodontopathies are caused by inflammatory processes involving the tissues surrounding and supporting the tooth; they cause a progressive decrease of the alveolar margin, exposing the root and allowing for bacterial penetration. The alveolar re-absorption can occur evenly and with the same extension in most teeth, or it can be localized around a single tooth. Moreover, a dental pocket can occur at the neck or at root level, inclined to an apical extension and leading to an abscess as a final outcome [26]. The alveolar re-absorption is classified as light when the junction-cement and alveolar margin is below 4 mm and as severe when the distance is greater.

Finally, there is an alveolar re-absorption and a bone remodelling where the tooth has been lost (*intra-vitam* loss).

1.1.5 Non-specific Stress Index

Many factors affecting metabolism, such as diseases, acute or chronic nutritional deficiencies, due to either a lack of consumption (direct) or of absorption (indirect), lead to an alteration of the bone tissue diagnosed through a macroscopic examination. The anthropological study has also detected these alterations (non-metrical indices on functional stress and on disease).

Porotic hyperostosis is a macroscopic porosity seen on the orbital roof (*cribra orbitalia*) and/or on the external surface of the cranial vault (*cribra cranii*). This alteration is related to anaemic states of different aetiology. For instance, hereditary haemolytic anaemias, anaemias following infectious or parasitic diseases, or anaemias due to an iron deficiency [27].

Exostosis is a bone formation in the external hearing canal and can appear as an irregular bone mass. Several clinical studies [28] have shown the onset of exostoses with a prolonged water exposition. Some types of dermatitis, traumas, haemorrhages and senile changes can lead to external otitis and so to exostoses.

Auricular osteophytosis, is due to light inflammation of the external ear. It manifests itself as a slight bone proliferation around the external acoustic meatus, leading to the formation of an irregular edge with small-size osteophytes. Both diseases, when present, have been indicated with a degree of severity: mild for up to 2 mm formations, severe for more than 2 mm formations.

Enamel hypoplasia manifests itself as lines or little wells on the teeth surface, and it is caused by the interruption or slowing down of the enamel formation during the amelogenesis, that is the growth phase of the permanent teeth (the period from birth to 6–7 years of age). These alterations are caused by non-specific stress factors (such as malnutrition or diseases), so they are useful indicators of the health condition and quality of life of a population [29].

Periostitis is an inflammation of the periosteum. The pathology can be mainly observed on the tibia surface, due either to microtraumas or venous stasis [30].

1.1.6 Musculoskeletal Markers, Arthropaties, Traumas

The bone tissue remodelling due to intense physical exercise or hard work is defined through ergonomic markers or MSM (musculoskeletal stress markers) [31] and MOS (markers of occupational stress). Among them, we can find enthesopaties, arthropaties, non-metrical stress and trauma markers.

Entheses (from the Greek enthesis, "introduction") are areas of muscular and ligament insertion [32]; in the absence of a specific biomechanical stress, they manifest on the bone as imprints (wrinkles, protrusions, cracks), and they represent variable indicators of strength. Under stress, the same points of insertion can show osseous proliferations and/or erosions, defined as osteophytosis and osteolysis. These alterations are due to a non-specific pathological state of the enthesis, generally called enthesopaty, which can be present or absent, while the strength signs are always recognizable.

These modifications can have a mechanical, metabolic or inflammatory origin.

Osteophytosis and osteolysis are also due to age or idiopathic factors of the bone's response to different stimuli: the border between a healthy and a pathological form is difficult to define.

Arthritis is a degenerative pathology of the joints of the post-cranial skeleton and of the intervertebral discs of the rachis, occurring with a marginal opening (lipping), osteophytosis, porosity and eburnation. These alterations are the result of a discrepancy between requested work and work capacity of the joint. Arthritis location, age of onset, spread and development have a multifactorial origin; even though the causes can have a systemic nature (ageing, hereditary factors, sex, obesity, etc.) and/or a local one (overload and joint dynamics alterations), biomechanical stress is the necessary condition for the development of arthritis.

As arthritis gets worse, and leads to a direct contact between the bone surfaces, these can become shiny (eburnation) and show stripes parallel to the direction of the joint movement, often accompanied by porosities [33].

Other types of non-metric markers of functional stress, defined as "discreet" MOS (Markers of Occupational Stress) [34] include all the extensions of the joint surfaces (squatting and Poirier optional facet, sacroiliac and Allen fossae), the lack of fusion of the ossification centres (acromial bone) and the vastus medialis muscle notch (also called Messeri patella), due to overload.

A Poirier's facet [35] is an extension of the articular surface of the head of the femur on the anterior surface on the neck, maybe due to a contact between the caput femoris and the margin of the acetabulum cavity, when the limb flexes and extends. A further etiologic factor can be a hard and repeated stress of the iliopsoas muscle, which presses on the medial margin of the cerebral prominence.

Both a prolonged crouched posture and a repeated flexion of the foot, when marching on rough ground [36], can cause the development of optional facets (squatting facets) at the level of the tibio-talar joint [7]. These features occur as an interruption of the continuity of the anterior margin of the tibial distal epiphysis.

The optional sacroiliac facets are round areas, localized at the level of the first or second sacral foramen, sometimes having their equivalent on the iliac tuberosities. These modifications are generally connected to loads carried on the back, with an increase of lumbar lordosis [7].

The Allen fossa, situated on the anterior face of the femoral neck, is connected to extensions and flexions of the limb [31]; it is the outcome of the contact of the rectus muscle tendon on the anterior part of the femoral neck. Its presence is due to an upright posture [33], associated to ambulation on steep ground [37–39].

Bipartite acromion, the potential outcome of an over use and load of the rotator cuff [40], is the lack of fusion of the acromion with the scapular spine.

Messeri patella [41, 42] is the result of the modification of the kneecap morphology. A frequent flexion of the legs or a habitual crouched position involves the quadriceps muscle tendon; its over stress leads to a lesion of the superior–lateral surface of the basis.

When studying the rachis, Schmörl hernias (the extroflexion of the inner fleshy nucleus from the vertebral body) have been taken into account. These nodes are related to traumas, ponderal overloads during adolescence or pre-existing conditions (infections, rickets and osteoporosis). These lesions are mainly found on the central portion of the lumbar vertebrae plateau and on the lower thorax [43]. The spinal column has also shown some osteophytoses, fractures and fusion of the bodies.

Among the most easily detectable alterations in the anthropological samples, traumatic lesions provide information on the environment and on the characteristics and hardness of the work carried out. The environment can cause particular physical traumas, recognizable on the skeleton: for instance, a high frequency of both wrist and ankle fractures can be due to working on irregular ground.

The bone remains have shown some traumatic lesions, such as fractures, dislocations, haematomas or pulled muscles. These have been recorded on an appropriate database, separating fractures/dislocations from tendon/muscle traumas.

Traumas are classified into accidental (due to life style), deliberate (due to violence), ritual, punishment (amputation) and therapeutic (surgical); their frequency, localization and severity can provide "traumatological patterns", useful for the analysis of the socio-cultural features of the ancient populations. Fractures are complete or partial interruptions of the bone structure integrity, leading to a healing process seen in new formations (osseous callus).

A dislocation is a permanent relocation of the joint surfaces. It is called complete when the loss of connection between the two surfaces is absolute. When partial contact remains, it is called incomplete or sub dislocation. Its aetiology can have a traumatic origin if occurring after a violent trauma which moves the ends of the bones; innate if due to a malformation of the ends of the bones; degenerative (pathological) if due to capsular ligament lesions.

1.1.7 Skeletal Markers of Working Activity

These markers increase in number and intensity with age, but also respond to mechanical stress [44]. The data regarding these alterations can be a useful parameter to trace a population's lifestyle [45, 46], thus contributing to the identification of load patterns and work division based on gender [47–49], or social status.

The muscular–skeletal stress markers have been recorded considering Hawkey [50] and Mariotti [51, 52] with three grades of development for every enthesis. The first grade (1), characterized by a weak and average development, is divided into three sub types: light (1a), low (1b) and average development (1c). The second (2) corresponds to a marked manifestation and the third (3) to a really strong development of the tract. These grades are all physiological: absent or normal modification.

Enthesopathies, when present, are divided in proliferative osteophytic forms (OF) (Figs. 1.7 and 1.8) and erosive, osteolytic forms (OL) (Fig. 1.9). The suggested pattern for their classification includes three grades that define the pathological stages. The first corresponds to light porosities and exostoses smaller than 1 mm; the second one to several areas of erosion and exostoses between one and four mm in size; the third one to marked exostoses, bigger than four mm. When there is no enthesis, or in case of a bad preservation status, the examined skeletal section has

Fig. 1.7 Enthesophytes at the insertion of the ulna triceps brachii. (Grave 176 Castel Malnome)

Fig. 1.8 Enthesophytes at the origin of the tibial soleus muscle (Grave 146 Castel Malnome)

Fig. 1.9 Erosion at the insertion of the costo-clavicular ligament (Grave 60 Quarto Cappello del Prete)

been recorded as "ND" (that stands for:. not detected). For the discrete markers, the presence/absence of traumas, fractures and arthropathies has been detected; for fractures and arthropathies also the site has been evaluated, recording the cases of politraumas.

1.2 History of Medicine in Rome

Valentina Gazzaniga and Silvia Marinozzi

Ancient Rome is, for the historian of medicine, an extremely rich reality due to the theoretical development, the available and highly intellectual, methodological and technical written sources, and the rich evidence provided by the archaeological findings and remains [53].

The chronological period, the anthropological and palaeopathological study dwells on in this book is one of the most representative of the whole ancient times: in Rome, a rich Italics heritage of herbal and therapeutic competence faces the medical knowledge acquired in Greece since the classical times, rising increasingly complex pharmacological theories, whose peak is Galen of Pergamon's "grades theory" but also the flourishing of encyclopaedic essays and manuals addressed to a wide and less refined public [55].

The worship of thaumaturgic gods, which only changes the name to the really wide number of Greek gods somehow involved in the treatment and in the promise of healing, is not only stifled by the importation of the rational medicine from Hippocrates, but, in a syncretistic way, it is enriched by the contributions from the Etruscan civilization first and then from the oriental esoteric religions; the survival of templar medical practices, which can be wholly superposable to the pre-classical and classical Greek ones, is well documented by Ovid's poetical tale on the importation of the worship of Asclepius and, in more recent ages and in a geographical and cultural Greek background, by the rhetorician Aelius Aristides' autobiographical *Sacred tales*, which tells his experience in healing.

As regards the rational medicine, the physicians claiming a medical training regularly gained in famous schools and teachers, have already learnt the lessons of the Hippocratic medicine suggesting a reworking which comes to an amazing complex degree (one of the most striking examples are Galen of Pergamon's writings) [54].

The heritage of the Alexandrian medicine, whose history is halfway the third century B.C. in a very short-term and extremely important period, is seen in Rome with a meaningfully increased anatomical awareness compared to the Greek experience: the human body, which was conceptualized as a hollow vessel intended to hold fluids in almost all the Hippocratic writings, is seen as an elaborate system of parts interacting to each other in the innovative Galenic medicine, completely able to exploit the Alexandrian Herophilus' and Erasistratus' medical experience on dissection and autopsy. Every part of the body has got its own function, which leads to health if successfully achieved; the change in the anatomical structure involves an impairment and so a disease [55].

The medical sects question the method as well as the epistemological nature of medicine [56]; the Empire opens up to imported cultural phenomena and faces with experiences, the therapeutic ones too, from the conquered countries and from the ones with an active trade, leading to wonderful opportunities of theoretical and practical enrichment particularly seen in pharmacopoeial works, as the *Compositiones*, dated around 47–48 A.D. and written by Scribonius Largus, a physician operating under emperor Claudius. In these works new substances of vegetable, animal and, in small percentage, mineral origin, spread by the maritime trade, meet the earliest pharmacological expertise, raising a really varied pharmacopoeia, where features of folk medicine merge, as well as the scientific ones. [57]

Moreover, in their preface letter sent to Callistus, Scribonius' *Compositiones* are an example of how the Roman medicine achieves original results as regards the moral and ethic thought; the suggestion to judge every patient equal and worth of treatment, even the enemies of the homeland, enriches a moral "inner" tradition coming from the Hippocratic Oath with new elements [58].

So, a very rich "medical marketplace" [59], characterized by different professional competences and by a progressive refinement of the medical knowledge comparing to the Greek origin, practised together by physicians from the Hippocratic tradition, traditional healers, specialist surgeons, obstetricians, priests of Asclepius and Gods and heroes skilled in the art of medicine, military doctors and slaves.

Consulting the several available historical sources, Roman Imperial medicine looks like a field of knowledge deeply related to the civil and social life, a field where different expectations and waitings join with an increasingly rising market demand [60]. The geographical borders expansion with the high variability of the socio-economic status of the inhabitants of the Empire, also followed by the change of the risk factors, of the onset conditions and spread of infectious diseases, in a word of the whole pathological background (called "pathocenosis" by Mirko D. Grmek, who coined a highly important neologism for the future study of the ancient Greek–Roman diseases) makes the Roman world a privileged place to investigate on the sanitary ancient history.

This work has favoured some of the available sources, because of their connection to the history of the treatment of orthopaedic injuries and trauma: first of all, the Hippocratic treatises, which directly or indirectly regard the healing of fractured and dislocated limbs, head trauma and wound's general treatment. As well-known, these works are not entirely attributable to the Kos master, although some of them were by the earlier reviewers, in particular Erotian, who lived under Nero, and author of a *Lexicon*, one of the first work trying to sort out the complex issue regarding the attribution of the works passed on under the name of Hippocrates. All these writings, however, share a rather early dating (end of the fifth – beginning of the fourth century A.D.) in unison with Hippocrates' real life span and are the basis of the "technical" reflection on a Roman "specialized" orthopaedic competence. In particular, operating from the medical and encyclopaedic point of view, Galen and Celsus regard them the starting point to process again bone, skeleton and limbs technology and intervention.

Celsus (1st cent. A.D.), as well known, has not got a medical background, but he is a highly brilliant data collector showing the best example of technical refinement ever reached in the Roman encyclopaedic field in his work *De Medicina*; in his survived book on surgery many pages regard the orthopaedic techniques and the description of the tools used for the treatment of bone injuries in Rome during the first Empire [61] .

Galen (130–200/210) is the well-known intellectual giant of medicine in antiquity; a versatile, very lucky and rich man, Marcus Aurelius' doctor first and then his son Commodus', he spends almost his whole life in Rome being on duty of the higher social classes. During his long Roman years, Galen collects books and makes up one of the most important medical library in the ancient times (destroyed by the Temple of Peace fire in 192 A.D. it was rebuilt by Galen himself, book by book, buying again what could be found on the market and writing "ex novo" his own works, when he didn't manage to find a copy among friends and acquaintances). His work, which survived almost entirely through the Syriac and Arabic translations, includes several essays on the treatment of fracture and dislocation, the instruments and technique [62].

The available written sources are very rich. We can also add the support of the material history, thanks to archaeology [63]: the healing temples, consecrated to Asclepius and to a huge number of principal and secondary deities, all involved in disease healing, which carry on their task during the Empire, a task confirmed by the richness of anatomical ex voto (Fig. 1.10a–c), a wide field of documents on diseases and deformity affecting the Romans and the Empire inhabitants, although unable to

Fig. 1.10 (**a**) Roman ex-voto: hand and foot, ca. I-II. Cent. A.D. (Museo di Storia della Medicina, "Sapienza" Università di Roma). (**b**) Roman ex-voto: harm, ca. I-II. Cent. A.D. (Museo di Storia della Medicina, "Sapienza" Università di Roma). (**c**) Roman ex-voto: foot, ca. I-II. Cent. A.D. (Museo di Storia della Medicina, "Sapienza" Università di Roma)

originally repeat the typologies already documented by the Greek and Etruscan clay production in forms and genres [64]; the treatment centres for slaves and soldiers (above all established at the borders of the Empire, the valetudinarian are complex buildings where wounded soldiers are admitted and where a military competence is practised, also extended to the orthopaedic treatments) [65]. We can add some most singular events: the ruins of private surgeries, as the Surgeon's House in Rimini, a second century A.D. building, where the Hellenic physician Eutyches lived and worked. When his house was destroyed by a fire, maybe in the third century after a barbarian raid, he left one of the richest surgical legacy of the ancient times; a hundred and fifty tools, of different material and dating, testifying their owner's high specialized level, and, maybe, the "military" origin of his medical knowledge [66].

Epigraphy helps to recreate the profile of the physicians working around the Empire, testifying the wandering features of the medical profession practised till the end of the Empire, excepting some cases concerning very famous physicians, settled for long periods in the same town. As regards, a slight difference between the practice of the Roman medical knowledge and its wandering organizational features in the Greek world, is the really wide dimension of the territories where doctors practice and the different cultures they meet: often coming from the eastern and Greek lands, not rare sepulchral statements testify their profession at the opposite edges of the great Empire.

A last notation goes to the "specialisms", characterizing the Roman medicine, unlike the classical Greek; the work of orthopaedists, eye specialists, doctors caring the women reproductive period and the first stages of the human life, surgeons of great technical competence, experts in difficult operations as trepanation, is documented by the equipment, by specific written works, as the case of Soranus of Ephesus' book on women diseases, and by important palaeopathological evidence [67]. In particular, a highly valuable example is the so-called Child of Fidene's skeleton (Fig. 1.11), belonging to the Soprintendenza Speciale per il Colosseo, il Museo Nazionale Romano e l'Area Archeologica di Roma and preserved in the Museum of the History of Medicine at the Sapienza-University of Rome. The outcomes of his trepanation testify a surgery performed only to relieve the pain caused by a cerebral tumour in a very young person, according to the technique described by Galen [68].

In the last years many valuable studies have regarded the different features of the intellectual and professional landscape of the art of medicine in Rome we have given a hint of; to mention the most meaningful contributions, the writings of V. Nutton, R. Jackson, D. Gourevitch, J. M. André, V. Boudon-Millot, V. Dasen, H. King, A. E. Hanson, M. Green, A. Krug, J. Scarborough, Ph. van der Eijke, L. Bliquez, I. Mazzini, S. Fortuna, S. Sconocchia, Ph. Mudry, F. Stok and A. Touwaide [69].

The study of these authors have demonstrated that the art of medicine in Rome is more than a simple reflection on the cultural background acquired from the classical Greece [70]; the new ideas, the outlook changes, the technological and methodological innovation make the Roman medicine a peculiar and highly complex competence, able to set again the "long terms" of its theoretical base unit adapting them to the sanitary and social needs of a very wide population, characterized by deep habits and customs differences.

Fig. 1.11 The child of Fidene, imperial age (Soprintendenza Speciale per il Colosseo, il Museo Nazionale Romano e l'Area Archeologica di Roma, at Museo di Storia della Medicina, "Sapienza" Università di Roma)

1.2.1 Orthopaedics, An Ancient "Specialty"?

Valentina Gazzaniga and Silvia Marinozzi

Generally speaking, ancient medicine is a non-specialized discipline. Hippocratic texts founding later medical rational tradition describe the image of a physician able to face fevers, cuts and traumas equally. Within this picture of generic medical competence, the surgical treatment of skin and skeletal lesions certainly fell into the category of the most successfully treatable medical practices [71]; in ancient times, traumatic lesions of varying origin must have been particularly frequent, due to wars, and accidental or occupational hazards (the type of lesions that wrestlers, gladiators or slaves employed for building or mining must have suffered): an empirical competence of their treatment had to be shared by the various health care "professionals". Hippocratic physicians, surgeons, medical practitioners and 'rhizotomoi' often dealt with traumas, assessed their outcome and gauged their potential complications from different perspectives, it being a chronic inflammation, a gangrene or an invalidating outcome [72] (Fig. 1.12a–c).

It is not surprising that in ancient Rome the competence of doctors who treated walking defects and limb problems in general rises to the level of specialistic discipline, capable of implementing some more practical features already belonging to the Greek Hippocratic medicine; the books of the *Corpus Hippocraticum* for general surgery and for the treatment of fractures and dislocations already had them, together with other scientific technical topics, such as obstetrics and pharmacology. Once again, it is not surprising

Fig. 1.12 (**a**) Roman surgical instruments, Imperial age (Museo di Storia della Medicina, "Sapienza" Università di Roma). (**b**) Roman surgical instruments, Imperial age (Museo di Storia della Medicina, "Sapienza" Università di Roma). (**c**) Roman surgical instruments, Imperial age (Museo di Storia della Medicina, "Sapienza" Università di Roma)

that orthopaedic competence has a high level of specialization in ancient Rome [73]; here, the highly educated Greek tradition (as transmitted by the Alexandrian sources) joins the empiric trait of the Italic and Roman tradition in a perfect balance.

1.2.2 "Noble" Origins

The theoretical lineage from the Greek Hippocratic knowledge is represented by the constant reference by Roman authors such as Celsus and Galen to a group of works belonging to the "Corpus"; these works document a rather high anatomical and osteologic competence: the essay "The Nature of Bones", which despite its title is a book on angiology, does contain a chapter on bones; the essays "Fractures and Joints", written by the same author between the end of the V and the beginning of the fourth century B.C. include directives on the treatment of arm and leg fractures, the reduction and treatment of dislocations of elbow and knee (Fig. 1.13), humerus and shoulder, collarbone, hip and fingers and correction techniques for backbone deviations; the essay "Mochlikos", already attributed to Hippocrates by Erotian, takes its name from the lever instrument used in the


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Non modò minùs moleſta ſunt, quàm quæ in primâ palmæ parte, ſed multò magis, quàm quæ in pede. Sed quoniam de pede & manu communiter tractauit, ideò abundè exiſtimat alterius partis duntaxat meminiſſe, quæ, quod ad moleſtiam pertinet, media eſt inter crus & pedem. quãto enim maiorẽ moleſtiam affert, quàm crus, tanto minorem, quàm pes, & præcipuè quàm calx, de quo paulo ſuprà egit.

NAm vel rotæ modiolũ defigere oportet, vel aliud quid ſimile: tum molli aliquâ re pedem obuoluere, bubuliſque loris latis circumligare, & eorum capita, vel ad piſtillum, vel ad aliud lignum deuincire, eiúſque imam partem, in modiolum demittere, ſummam recuruare: alios verò & ab humeri capite, & à poplite in contrariam partem extendere.

A Rotæ modiolus.
B Lorum latum.
C Piſtillum.
D Ab humeri capite extendentes.
E A poplite extendentes.

Lignum defigi iubet, quod recipere poſſit imam partem vectis, per quem membrum debet ab inferiori parte extendi. tibi verò ignotum eſſe non credo, rotæ modiolum πλήμνην ab Ionibus appellari. cùm apud poëtam hoc quoque vocabulum legatur. Commonet autem Hippocrates, vt vbique ex ijs, quæ ad curationem conducunt, illis vtamur, quæ in promptu ſunt: & nunc etiam meminit modioli rotæ, qui præſto nobis eſſe poteſt vbiuis gentium: ſimiliter piſtillo pro vecte nunc ad extendendum vtitur. Sed quâ viâ adhiberi hæc debeant, ipſe ſuis verbis, ſi animaduertantur, apertè declarauit.

SEd à ſuperiori quoque parte adhibere vim licet.

Vim, hoc eſt, valentem in vtramque partem intentionem ἀνάγκην appellauit, vt vehementem eius potentiam indicaret.

Fig. 1.13 Repairing dislocated knee from Guido Guidi, Chirurgia e Graeco in Latinum conversa, 1544 (Wellcome Library) reduction of fractures and dislocations; the essay *Head Injuries*, dating between the end of the V and the beginning of the fourth century, is a very technical text giving indications on the correct clinical approach towards a patient with head injury, who may need both specific diagnostic techniques, and specialized skills in the use of drilling tools. These essays all address a type of treatment which would be nowadays defined as "orthopaedic", and extracts from other works can also be added to them, for example "The doctor's workshop", with the description of mechanical tools for the reduction of dislocations and fractures, among which Hippocrates' s bench (Fig. 1.14); how to build this traction table was already found in the text *Joints*, and it will be discussed by future generations of doctors, from Rufus from Ephesus, to Galen, Oribasius and Paul from Aegina, thus becoming a very popular topic, and the reference point for corrections and constant modernizations that will occur in the history of orthopaedic surgery up until the modern era [74]. Most probably, some orthopaedic information must have been contained in a lost work by Hippocrates on war injuries, where working as an army physician was recommended as a way to acquire anatomical knowledge and rapidly effective therapeutic techniques [75]. Since its origins, a specific feature of the ancient orthopaedic competence is the self-perception of how spectacular the techniques of intervention on the bone are; the use of considerable tools, such as beams or ladders to hang the patient and bring the dislocated bone back to its anatomical site (Fig. 1.15), but also the immediate perception of the healing process and the external visibility of complex bandaging techniques, make orthopaedics an easy field to acquire fame and consensus, and to impress patients even without especially high medical qualities. A good doctor must regard orthopaedic tools – swings, levers, ladders and benches (Fig. 1.16) – as what they actually are tools that are often not designed for therapeutic goals, but directly borrowed from carpentry or other forms of craftsmanship, just like some other surgical tools for orthopaedic use, survived because they were made of metal, and difficult to identify today even by an archaeologist specialized in the history of ancient surgical instrumentation [76]. Tools cannot replace the doctor's professional skills, just like a planer, a saw, or a hammer cannot guarantee a good carpenter's work: "… the same is true for mechanical tools: they must be conceived correctly or not conceived at all: it is dishonourable and contrary to art when mechanical tools are designed to take the talent away from their designer" [77]. (Fig. 1.17). Orthopaedics, like any other branch of Hippocratic medicine, finds its ethical justification in its being correction "according to nature", a balanced technique which can bring things back to their natural course, where disease is its temporary discontinuation [78]. Its main goal is to limit a potential permanent damage caused by an error in the bone

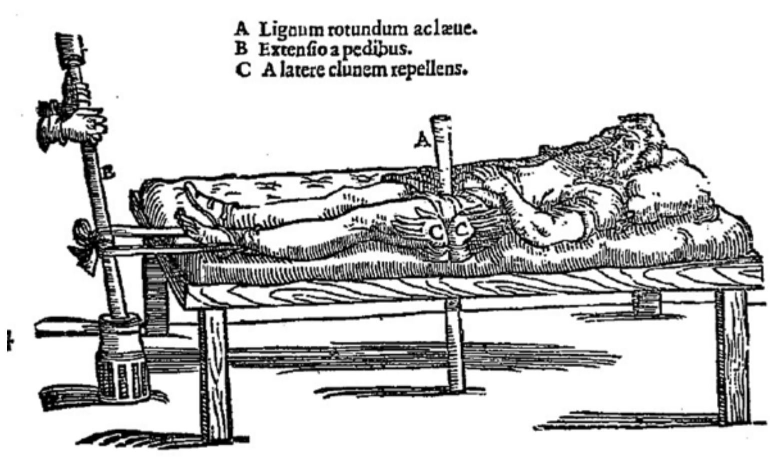


Fig. 1.14 Scamnum (Hippocratic bench), from Guido Guidi, Chirurgia e Graeco in Latinum conversa, 1544

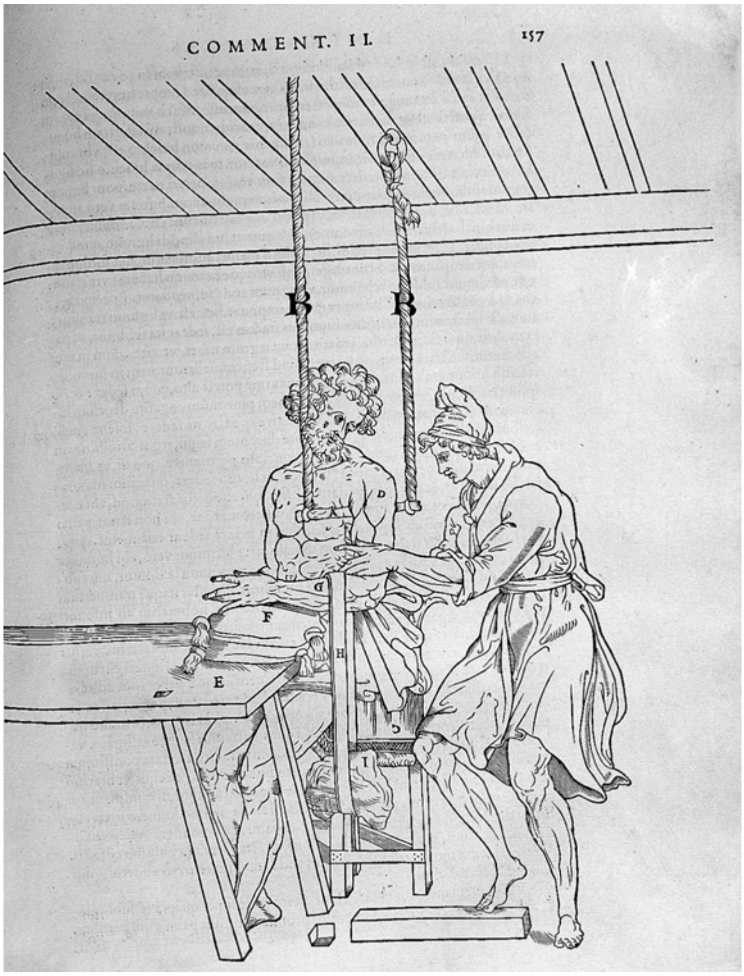


Fig. 1.15 Repairing a dislocation to the arm, from Guido Guidi, Chirurgia e Graeco in Latinum conversa, 1544 (Wellcome Library)

remodelling; the main interventions on fractures, for instance, include the removal of minute particles, the filing of the fracture's indented margins, the chiselling of overabundant or defective bone callus or the correction of congenital bone deformities [79] (Fig. 1.18a, b). All unnecessary pain must be limited, if not avoided; to this aim, an in-depth knowledge of the nature and arrangement of bones, together with the careful respect for the patient's needs are helpful; the faster the medical act, painful in itself, the more competent and morally correct. Medical texts and palaeopathology both offer the perception of the profound and impressive technical expertise required to bone surgeons: the high number of well-healed bone fractures on ancient human finds suggests good levels of treatment, even though a spontaneous healing can be hypothesized in most cases, also favoured by patients' long periods of immobilization and consequent care [80]. Immobility could also be guaranteed by specific items, such as wooden crates or cages made of flexible sticks tied together and bandaged to the broken limb; the use of long strips of bark and fresh soft branches is documented in pharaonic Egypt, in the Iron Age in Italy, and in the eruption of Mount Vesuvius in 79 by a young fugitive from Ercolano, who was forever immortalized by the lava together with the ferula blocking his fractured arm [81]. An increasing "orthopaedic" competence is also

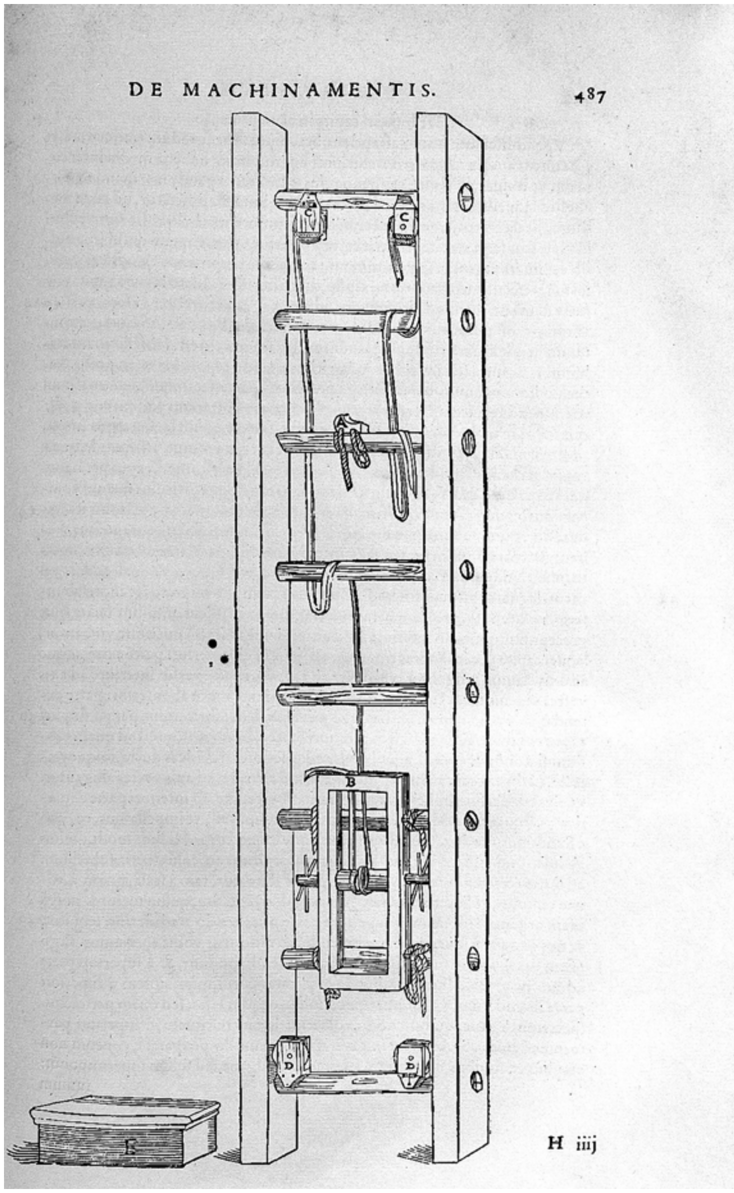


Fig. 1.16 Orthopaedics ladder, from Guido Guidi Chirurgia e Graeco in Latinum conversa, 1544 (Wellcome Library)

documented in the indirect tradition [82], which has passed on information about lost texts of medical authors, known as the inventors or renovators of tools for surgical correction of the bone: from Diocles of Carystus (fourth century B.C.), to Philotimus (IV B.C.), both specialized in the reduction of femur dislocation, to Nilaeus (III-I B.C.), the inventor of tools for the correction of out-of-site femur and humerus (Fig. 1.19), to Protarcus (II-I cent. B.C.) and Megetes (I B.C.), specialized in the knee; from Heliodorus (first century), with his technique of jaw reduction, to Archigenes (I-II cent.), an expert in amputation techniques, an increasing surgical specialization seems to have been established in the long series of centuries between the Hippocratic texts and their reinterpretation in Roman times, mainly by Celsus [83] and Galen.

Fig. 1.17 Roman Surgical Instruments, Imperial age (Museo di Storia della Medicina, "Sapienza" Università di Roma)

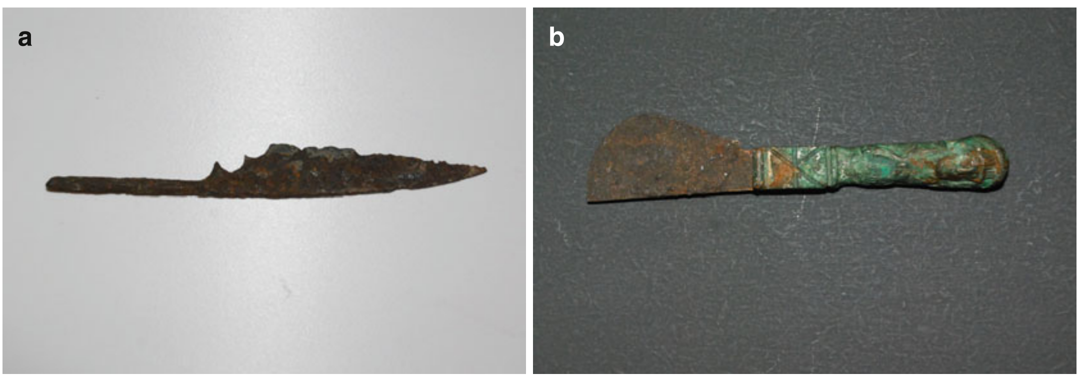


Fig. 1.18 (**a**) Roman surgical knife (Museo di Storia della Medicina, "Sapienza" Università di Roma). (**b**) Roman surgical knife (Museo di Storia della Medicina, "Sapienza" Università di Roma)

1.2.3 Orthopaedics in Rome

In Imperial Rome, the spectacular nature of some bone correction methods, already criticized in Hippocratic texts, seems to diminish; thus, the techniques are simpler than those described in Hippocratic texts, but the number of pathological situations where they can be used increases. Celsus and Galen, the main authors who provide indications on bone treatment in Rome, refine ancient techniques and propose innovative uses. In the *De Re Medica*, Celsus gives a more practical and realistic view of doctors' and surgeons' "modus operandi"; even with his pathological interpretations and some specific therapeutic treatments of Hippocratic tradition, Celsus is mainly interested in the praxis. On the other hand, Galen represents the Greek medical philosophical culture, and mirrors a Hippocratic approach also in the re-elaboration of orthopae-

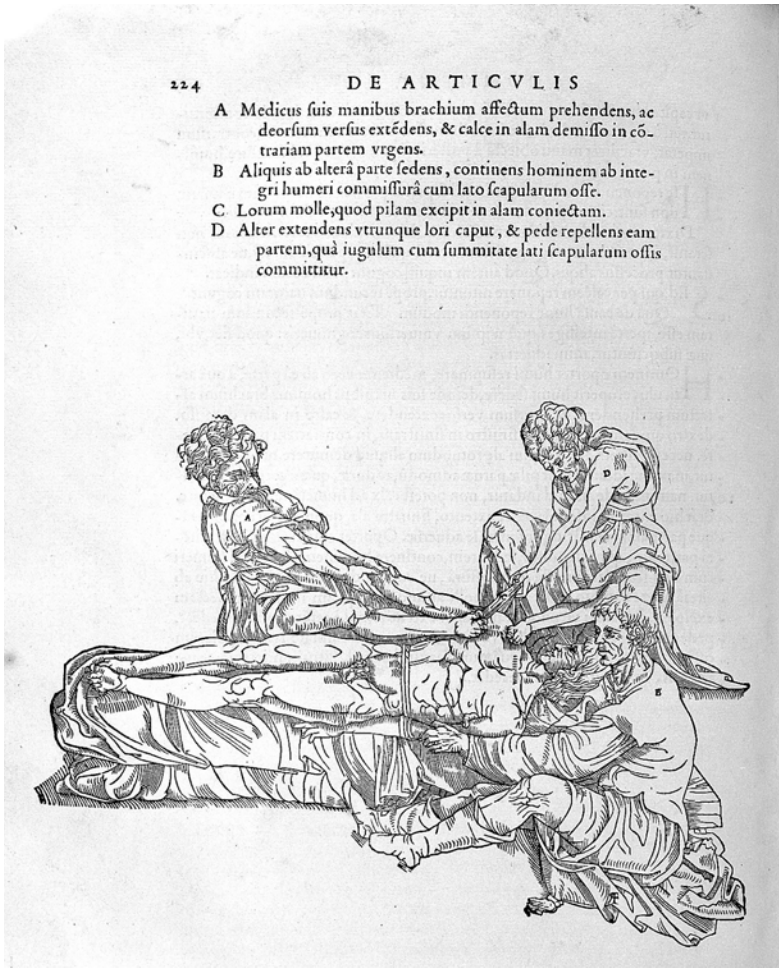


Fig. 1.19 Repairing broken arm, torn ligament or shoulder dislocation, from Guido Guidi, Chirurgia e Graeco in Latinum conversa, 1544 (Wellcome Library)

dic surgery through the Alexandrian tradition, which had enriched it with the design of new mechanical tools [84]. In his philosophical view, the animal body is formed from the matter of masculine and feminine seeds, which collect and hand down the most refined and vital part of the humours and generate the three primary organs, the heart, the liver and the brain; arteries, veins and nerves develop from each of these organs. They instil matter and life into the other parts of the body, and the bone structure forms around them (thanks to the action of the animal bodies' earthy component giving solidity and hardness, of air moving and giving vital wind, and of heat). In this perspective, the skeleton is given the role of protecting the vital organs, since the first part to be developed is the rib cage, and then, as in a process similar to the development and ramification of vegetables (Galen thinks of trees in particular), come the spine and the skull; after that, when the connective tissues and the muscles form around the bones, the skeleton becomes the basic structure, which enables us to be supported, move and stand [85]. In his *Commentaria* to Hippocratic works on orthopaedics, in particular the *De articulis* and the *De fracturis*, and in other less specific ones, such as the *De medici officina*, *De usu partium*, *De methodo Medendi*, *De fasciis*, Galen implements the original doctrine with the description of techniques and tools, refined and developed over time, and most of all with clinical cases observed by later authors and by himself. It is the case of humerus dislocation which Hippocrates believed occurring only inferiorly or anteriorly, because the head of the humerus can move forward while staying underneath the protrusion of the shoulder blade. Later Greek authors and Galen himself describe posterior and lateral (external) dislocations, mainly frequent in wrestlers because of the twisting movements they undergo; the same is true with the knee, which can dislocate laterally for the same reason. Celsus and Galen view the orthopaedic techniques differently: Celsus reflects the typical Roman encyclopaedic approach and the orthopaedical remedies and techniques he observes in Roman daily medical practice. On the other hand, both Celsus and Galen adopt a common method of explaining skeletal diseases of non-traumatic origins: they think an innate weakness or an inappropriate diet lead to heat deficiency and humoural imbalance. They both reclaim ancient indications in order to perfect them and propose some innovative uses. One example is the drilling of the skull, generally used to remove bone fragments, coming from compound fractures, that might damage the brain and induce humoural plethoras, accumulations of pathologic fluids, something very similar to our concept of infection; or, as is suggested in Galen, to allow the free flow of cerebral pneuma, which could be compromised by a depressed fracture, but also for the treatment of epilepsy or of persistent headaches [86] (Fig. 1.20).

Fig. 1.20 Drilled skull of the child of Fidene (Soprintendenza Speciale per il Colosseo, il Museo Nazionale Romano e l'Area Archeologia di Roma, at Museo di Storia della Medicina, "Sapienza" Università di Roma)

Among the most spectacular techniques available to ancient doctors, the drilling with the use of circular or crown drills (modiolus), or with the combined use of chisels (Fig. 1.21) to bore the circular section of the skull to be removed, also represents the therapeutic model for the removal of bone fragments in compound fractures of other skeletal parts [87]. Other specialistic and visibly striking interventions are those performed with the Hippocratic bench, a dedicated orthopaedic bed equipped with levers, strings and tie-rods for the extension and the reduction of fractures and dislocations; however, both Celsus and Galen also report less complex, but more widely performed procedures used by surgeons to reduce humerus, femur and vertebral dislocations, but also spine incline, using a simple ladder (Fig. 1.22), either to lever on the rungs in rearrangement operations for humerus or femur dislocation, or for "succussions", performed tying the patient along the ladder and repeatedly moving it vertically to treat hunchback and vertebral inclinations [88]. A "retrospective diagnosis" is difficult and risky, given the theoretical adhesion to a strictly humoural model: with an analysis of the written sources only, it is difficult

Fig 1.21 Roman Chisel, ca I-II cent. A.D. (Museo di Storia della Medicina, "Sapienza" Università di Roma)

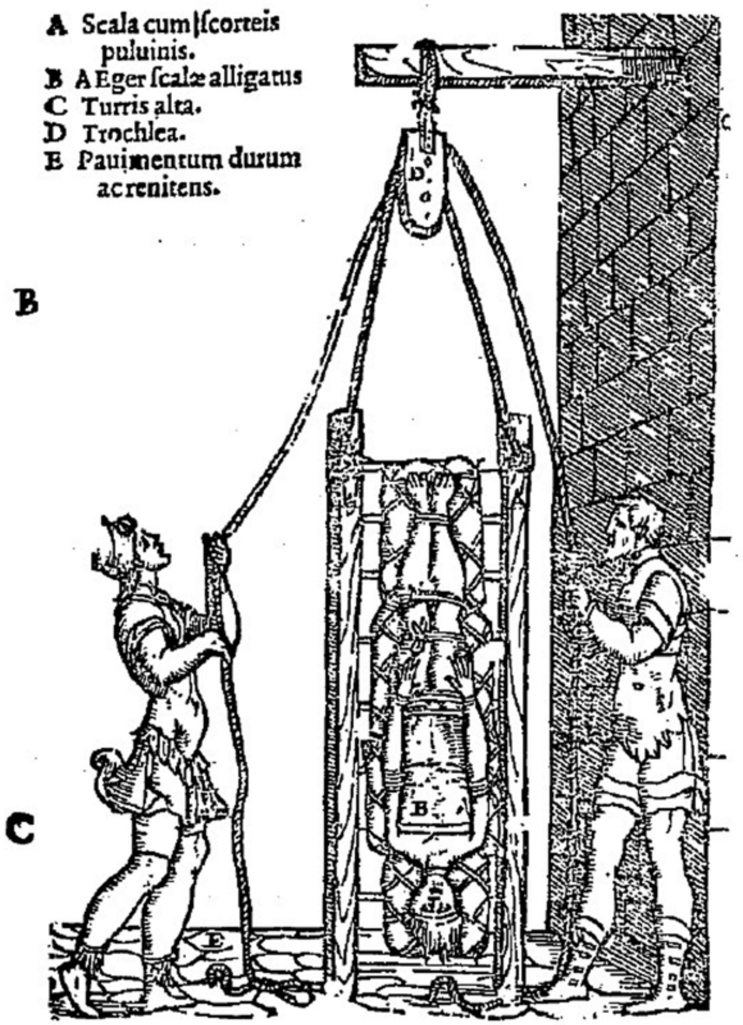


Fig. 1.22 Ladder for vertebral dislocation, from Guido Guidi Chirurgia e Graeco in Latinum conversa, 1544

to distinguish between rheumatic pathologies, pathologic arthritis or arthritis following excessive wear, load or strain from a simple description of symptoms. Pains in hands and feet, for instance, are often classified as podagra and chiragra, while the symptoms are nowadays attributable to a form of gout, which does not have a nosological classification in ancient times (Fig. 1.23a, b).

The same goes for the complex range of neoplastic diseases, whose description belongs to the ancient categories of "karkinos" or "phyma", but does not allow distinguishing a potentially malignant development from simple protrusions and swellings. Without a specific nosology to distinguish the various pathological processes, skeletal disabilities, including fractures and recurrent dislocations, are just a sign of innate weakness or inappropriate diet. This is why therapies are generally based on soothing compresses and local analgesics, diet, rest, laxatives, enemas and repeated bloodletting, so as to drain the corrupted humours clogging the lesioned part and leading to inflammation.

1.2.4 An Advanced Technique

The problems in the pathological interpretation are counterbalanced by the huge amount of data

FIG. 1.23 (**a**) Roman ex-voto: hand, ca. I-II. Cent. A.D. (Museo di Storia della Medicina, "Sapienza" Università di Roma). (**b**) Roman ex-voto: feet, ca. I-II. Cent. A.D. (Museo di Storia della Medicina, "Sapienza" Università di Roma)

about therapies coming from Roman sources: it is particularly important for the historian to work together with physical anthropology and palaeopathology, which approach skeletal diseases and dysfunctions objectively, and allow tracing a consistent therapeutic and *pathocenotic* picture [89]. In Celsus and Galen, the corrective treatment of fractures and dislocations confirms the high level of structural knowledge of the skeleton and the muscular system reached through animal dissections, but also the high level of technical specialization of Roman surgery in the Imperial time. A high level of technical expertise is documented in very interesting sources, such as the so-called Child of Fidene, a find from Imperial Rome, now owned by the Soprintendenza Speciale per il Colosseo, il Museo Nazionale Romano e l'area archeologica di Roma and treasured at the Museum of Medical History of Sapienza-University of Rome. It documents a drilling technique which is very close to the Galenic model, and more complex than the techniques adopted for the simple removal of fractured segments from the skull [90]. The Child of Fidene actually shows the intracranial signs of a mass probably causing a considerable increase in endocranial pressure and, as a consequence, marked pain; there must have been the drilling and removal of a circular bone fragment to ease the symptom at least for some time [91]. Such a high surgical level is shown in the use of specific techniques of orthopaedic correction, of a specialized surgery and set of tools; and whereas Galen describes the various treatments and respective tools in detail, including their design, Celsus just mentions the more complex ones, and describes in detail the easier methods, the ones more commonly used by Roman surgeons. An example of such difference is the fastidiousness that Galen uses in his meticulous description of design, elements and uses of the Hippocratic bench for the reduction of fractures and dislocations of femur, vertebrae, long bones of lower limbs and ankle [92]; on the other hand, Celsus just mentions it as the tool of choice and of highest efficacy, without specifying its structure and functioning. In the absence of the Hippocratic bench, both Galen and Celsus provide precise indications on an alternative set of tools that can be used successfully: the extension can be performed with strings tied to the regions to be pulled, and connected to sticks (Fig. 1.24), so as to favour the traction in opposite directions; in case of fractures and dislocations of the lower limbs, two sticks can be set under the armpits to hold the body during the traction. The reduction and bandaging must be performed during the limb's extension, with manual replacement of the bone, and starting the bandaging from the protruding section of the dislocation; the use of more than one pad and one round of bandages allows the physician to make a greater pressure [93]. After this initial treatment, the affected part must be immobilized and positioned higher than the

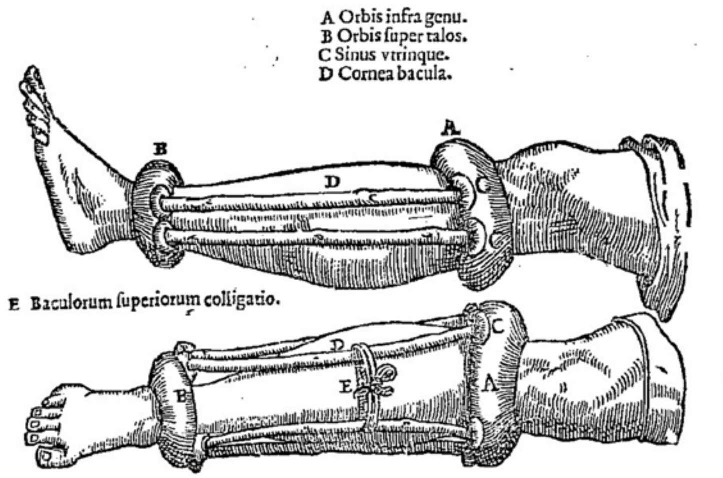


Fig. 1.24 Reduction of leg fracture, from Guido Guidi, Chirurgia e Graeco in Latinum conversa, 1544

Fig. 1.25 Roman ex-voto: leg, ca. I-II. Cent. A.D. (Museo di Storia della Medicina, "Sapienza" Università di Roma)

rest of the body. The foot and the leg can be supported by a soft pillow. As a last option, not completely aligned with Hippocrates's rules of conduct, surgeons can use a ladder. The indications to reduce diaphysial fractures of tibia, fibula, humerus, ulna and radius are also similar; both authors recommend methods of extension with the use of bandages and pulls and in site repositioning of the bone, holding it in the correct position with repeated wrappings at different degrees of pressure (Fig. 1.25). We already mentioned the technique with wooden sticks inside the bandaging that Celsus calls ferulae [94]. A few years ago, one of these ferulae was identified by Luigi Capasso and his team, in the form of partially burnt grapevine wood fragments, on the arm of a child from Ercolano (case E8) with a double fracture of the right forearm, probably occurred 6 or 7 weeks prior August 25th, 79 [95]. In case of jaw fractures, the dislocated teeth must be tied with a gold or silk thread (a dental technique documented on Etruscan bone samples and inherited and well documented in Roman medicine), and then the bone must be immobilized with bandages. Galen suggests a peculiar type of bandage [96]: a strip of Carthage leather is stuck under the chin with some rubber, while another strip is applied starting from the fractured section; the two laces will be tied together on the head; in this way, a permanent traction better guarantees the reduction of the fracture (Fig. 1.26). The indications for the treatment of humerus and ankle fractures, and of dislocations, especially of the humerus, the femur and the vertebrae, are particularly detailed due to two reasons: the importance of reduction and bandaging methods when restraining or immobilizing structures are impossible; the high risk of stiffness and the frequency of irreversible inflammatory processes, that lead to gangrene, sepsis and death of the patient.

Fig. 1.26 Jaw bandage, from Guido Guidi, Chirurgia e Graeco in Latinum conversa, 1544

1.2.5 A Rich Set of Tools

In different and complementary ways, both literature and archaeology offer evidence of the tools used for the therapy of orthopaedic lesions. The archaeological findings from the digs in Ercolano, Pompei, the Domus of the Surgeon in Rimini and other sites [97], have allowed to grasp the uses and orthopaedic applications of chisels, bone levers, ostagrae (forceps for bones) cauteries, osteotomes and drills (Fig. 1.27a, b); these tools have survived, at least in their metallic parts, well enough to be evidence of the organizational techniques of ancient surgical tool sets. Other tools, made of wood or of other perishable materials, have only been passed on through their descriptions: among these, the already mentioned orthopaedic bench. This is made up of a board, with side groovings deep enough to fit the levers used as extenders and brakes. The external end is equipped with supports for planks holding in place the ropes tying the patient; the median section has a hole to fit the pole used for counter-extension; two pestles are secured to the two ends of the board, to tie the ropes and achieve a balanced extension [98] (Fig. 1.28). In fractures of the lower limbs, Galen suggests the glossocome, a sort of lime wood crate – its name reminds us of the one of a jewellery box largely employed in the Greek region Attica – with a platform to put the foot on. Two holes at the sides of the board hold the laces used to tie the extremities of the bones to be reduced, and go through hoists, so as to impose a continuous pressure and keep the bones in place. The ropes are composed of two strips each; the ones belonging to the lower rope go through the holes in the board, while the ones used for the upper tying slide through wheels, and reach the pole at the end of the glossocome. The extension is performed by simply turning the wheels to pull in opposite directions. The small boards are only positioned in the middle section of the leg, and in the areas near the joints in general, and not at its extremity, so as to avoid compression, and consequent further inflammation and ulcers [99] (Fig. 1.29). A similar device is described by Celsus for fractures of the femur, the knee and the leg: the bandaged limb is positioned into a canal with two holes for any drainage, and a support blocking the foot from sliding; the sides have holes for the laces tying the tool to the leg. In fracture of the femur, the canal holds the whole limb, from foot to hip, but can also just reach the knee [100]. Another restraining tool is the shower, a wooden concave structure, modelled to hold the leg or parts of it, a sort of premanufactured cast to immobilize it. Specific tools are described, both by Celsus and by Galen, for surgery of exposed fractures, where dressing of the wound is essential, together with the removal of fragments and sharp sections of bone stumps, which might tear the flesh. Galen proceeds to the reduction of the fracture by repositioning the bones using levers to lift and lower the bone stumps during extension; he uses the wedge to remove fragments that might cause further lesions, and the axis wheel [101] (Fig. 1.30). For limb reduction, he uses a tool composed of two leather rings positioned at the ends of the bone to be extended. These rings may be concave or pierced, so they can fit sticks of varying

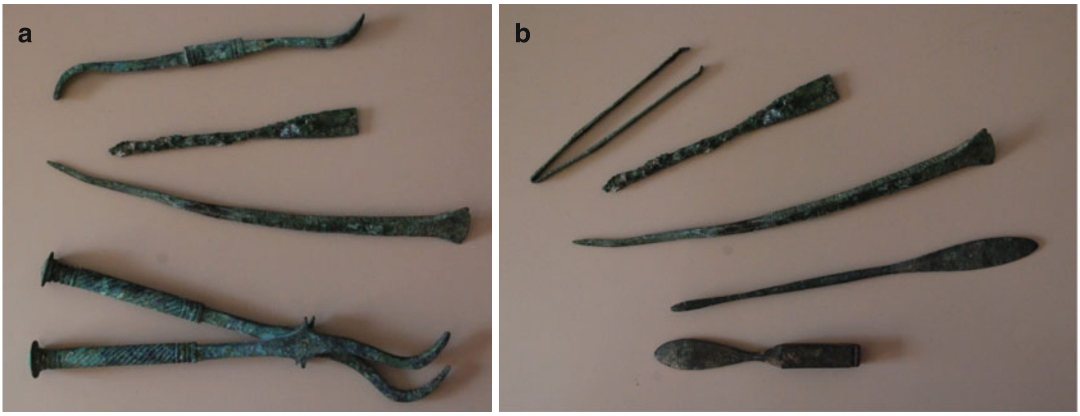


Fig. 1.27 (**a**–**b**) Roman Surgical Instruments, Imperial age (Museo di Storia della Medicina, "Sapienza" Università di Roma)

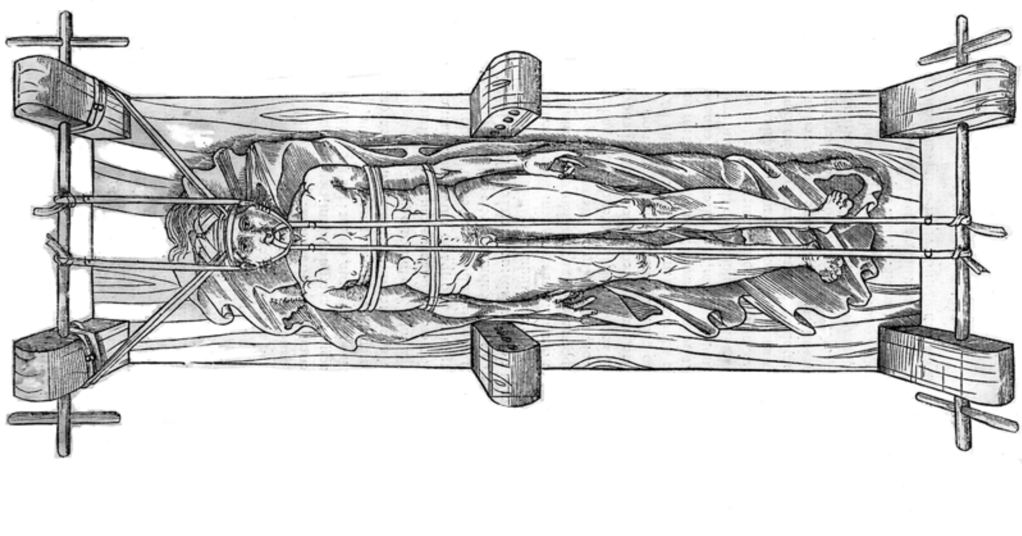
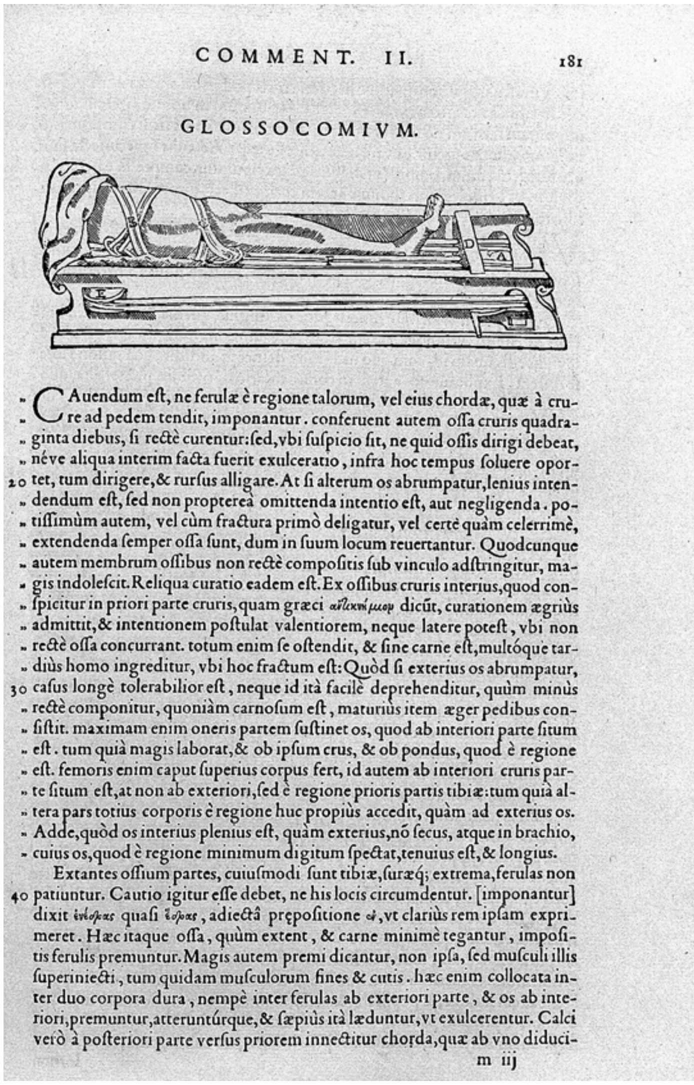


Fig. 1.28 The Hippocratic Scamnum (bench) for the correction of dislocation, from Guido Guidi, Chirurgia e Graeco in Latinum conversa, 1544 (Wellcome Library)

length made of a rather elastic wood, capable of a natural pressure inducing bone extension [102]. Celsus cuts and files the sharp points using chisel and pincers, and inserts a small smooth pole into the wound; the pole naturally pushes the two stumps to distance and align them, and avoid the formation of bone callus. If the bones have stabilized, cutting through the flesh or shortening or deforming the limb too much, the bone callus must be removed, the stumps must be taken out and repositioned, and a bandaging must be wrapped with a stick pressing on the protruding section of the bone to align it [103]. In the most severe compound fractures, even the bandaging might compress the parts too much and sharpen the inflammation, so doctors


COMMENT. II. 181

GLOSSOCOMIVM.

CAuendum eſt, ne ferulæ è regione talorum, vel eius chordæ, quæ à crure ad pedem tendit, imponantur. conferuent autem oſſa cruris quadraginta diebus, ſi rectè curentur: ſed, vbi ſuſpicio ſit, ne quid oſſis dirigi debeat, néve aliqua interim facta fuerit exulceratio, infra hoc tempus ſoluere oportet, tum dirigere, & rurſus alligare. At ſi alterum os abrumpatur, lenius intendendum eſt, ſed non propterea omittenda intentio eſt, aut negligenda. potiſſimùm autem, vel cùm fractura primò deligatur, vel certè quàm celerrimè, extendenda ſemper oſſa ſunt, dum in ſuum locum reuertantur. Quodcunque autem membrum oſſibus non rectè compoſitis ſub vinculo adſtringitur, magis indoleſcit. Reliqua curatio eadem eſt. Ex oſſibus cruris interius, quod conſpicitur in priori parte cruris, quam græci [illegible] dicũt, curationem ægriùs admittit, & intentionem poſtulat valentiorem, neque latere poteſt, vbi non rectè oſſa concurrant. totum enim ſe oſtendit, & ſine carne eſt, multóque tardiùs homo ingreditur, vbi hoc fractum eſt: Quòd ſi exterius os abrumpatur, caſus longè tolerabilior eſt, neque id ità facilè deprehenditur, quùm minùs rectè componitur, quoniàm carnoſum eſt, maturiùs item æger pedibus conſiſtit. maximam enim oneris partem ſuſtinet os, quod ab interiori parte ſitum eſt. tum quià magis laborat, & ob ipſum crus, & ob pondus, quod è regione eſt. femoris enim caput ſuperius corpus fert, id autem ab interiori cruris parte ſitum eſt, at non ab exteriori, ſed è regione prioris partis tibiæ: tum quià altera pars totius corporis è regione huc propiùs accedit, quàm ad exterius os. Adde, quòd os interius plenius eſt, quàm exterius, nõ ſecus, atque in brachio, cuius os, quod è regione minimum digitum ſpectat, tenuius eſt, & longius.

Extantes oſſium partes, cuiuſmodi ſunt tibiæ, ſuræq; extrema, ferulas non patiuntur. Cautio igitur eſſe debet, ne his locis circumdentur. [imponantur] dixit [illegible] quaſi [illegible], adiectâ prępoſitione ἐν, vt clariùs rem ipſam exprimeret. Hæc itaque oſſa, quùm extent, & carne minimè tegantur, impoſitis ferulis premuntur. Magis autem premi dicantur, non ipſa, ſed muſculi illis ſuperiniecti, tum quidam muſculorum fines & cutis. hæc enim collocata inter duo corpora dura, nempè inter ferulas ab exteriori parte, & os ab interiori, premuntur, atteruntúrque, & ſæpiùs ità læduntur, vt exulcerentur. Calci verò à poſteriori parte verſus priorem innectitur chorda, quæ ab vno diduci-

m iij

Fig. 1.29 The Glossocomium, from Guido Guidi, Chirurgia e Graeco in Latinum conversa, 1544 (Wellcome Library)

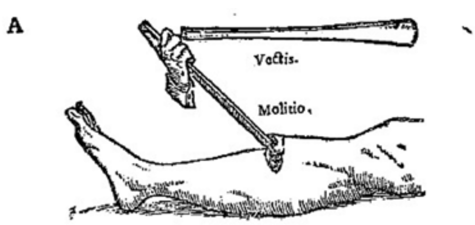
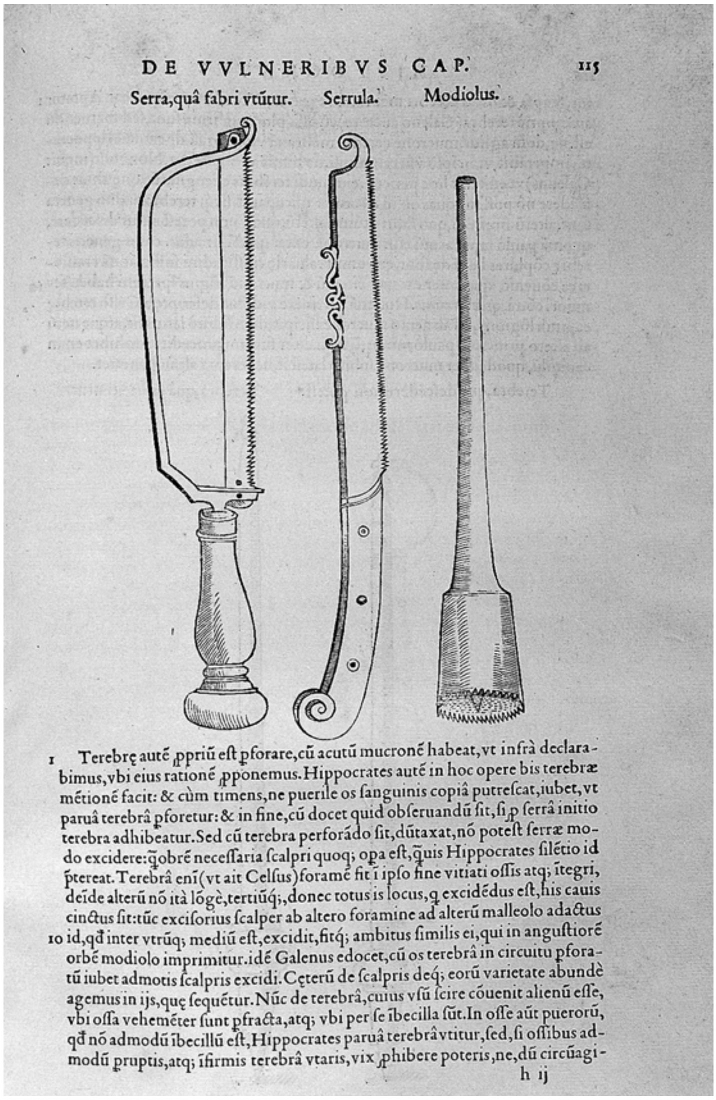


Fig. 1.30 Treating exposed fractures, from Guido Guidi, Chirurgia e Graeco in Latinum conversa, 1544

should only dress the wound, and prescribe fasting, rest and absolute immobilization of the limb. Celsus describes exostotic formations of the bones, which discolour or develop ulcers or fistulas, which can progress and eventually erode them; if this is the case, surgeons must use a cautery, and a tool to curette the bone, and drain the blood. By digging into the cavity as far as the hard part containing black matter, the tissue must be removed until the bone is completely white. For this intervention, Celsus uses the drill or the modiolus (Fig. 1.31); the latter is composed of a pierced stick, fitted with a second stick ending in a metal cylinder with a saw-toothed lower edge. The trephines are screwed into this edge; the handles of the bow are pierced and hold the


DE VVLNERIBVS CAP. 115

Serra,quâ fabri vtũtur. Serrula. Modiolus.

Terebrę autẽ ꝓpriũ eſt ꝑforare,cũ acutũ mucronẽ habeat,vt infrà declarabimus,vbi eius rationẽ ꝓponemus.Hippocrates autẽ in hoc opere bis terebræ mẽtionẽ facit: & cùm timens,ne puerile os ſanguinis copiâ putreſcat,iubet,vt paruâ terebrâ ꝑforetur:& in fine,cũ docet quid obſeruandũ ſit,ſi ꝓ ſerrâ initio terebra adhibeatur.Sed cũ terebra perforãdo ſit,dũtaxat,nõ poteſt ſerræ modo excidere:q̃obrẽ neceſſaria ſcalpri quoq; opa eſt,q̃uis Hippocrates ſilẽtio id ꝓtereat.Terebrâ enĩ(vt ait Celſus)foramẽ fit ĩ ipſo fine vitiati oſſis atq; ĩtegri, deĩde alterũ nõ ità lõgè,tertiũq;,donec totus is locus,q excidẽdus eſt,his cauis cinctus ſit:tũc exciſorius ſcalper ab altero foramine ad alterũ malleolo adactus id,qđ inter vtrũq; mediũ eſt,excidit,fitq́; ambitus ſimilis ei,qui in anguſtiorẽ orbẽ modiolo imprimitur.idẽ Galenus edocet,cũ os terebrâ in circuitu ꝑforatũ iubet admotis ſcalpris excidi.Cęterũ de ſcalpris deq́; eorũ varietate abundè agemus in ijs,quę ſequẽtur.Nũc de terebrâ,cuius vſũ ſcire cõuenit alienũ eſſe, vbi oſſa vehemẽter ſunt ꝑfracta,atq; vbi per ſe ĩbecilla ſũt.In oſſe aũt puerorũ, qđ nõ admodũ ĩbecillũ eſt,Hippocrates paruâ terebrâ vtitur,ſed,ſi oſſibus admodũ ꝑruptis,atq; ĩfirmis terebrâ vtaris,vix ꝓhibere poteris,ne,dũ circũagi-

h ij

Fig. 1.31 Surgical instruments including Modiolus, from Guido Guidi, Chirurgia e Graeco in Latinum conversa, 1544 (Wellcome Library)

thread turning around the toothed crowns of the drill (it is pulled alternately from both sides to turn the trephines and bore a hole in the part to be removed). For wider and deeper lesions, surgeons use the drill, with a bit which enlarges itself and withdraws a larger amount of bone; some holes are bored around the affected area, so as to remove the whole affected area with a chisel [104]. In patients with recurrent joint dislocations of the humerus, especially if cartilage and bone tissue consumption is present, Galen cauterizes the armpit tissues to bore holes and insert a thin spatula to lift the skin and perform another eschar in the middle, with a thinner cautery, until he touches the shoulder blade. If necessary, some more cauterizations are performed anteriorly, to remove the tissues and directly handle the joint's cap [105].

Given the pain and crudeness involved, ancient medical competence must have been hard to bear, which goes to justify Galen's patients, whom he describes as willing to lie, in order to escape huge suffering [106].

This chapter is the product of collaboration of Valentina Gazzaniga and Silvia Marinozzi, Sapienza – University of Rome and is therefore attributable in equal measure to both the authors.

1.3 Basis of Palaeopathology

Carla Caldarini, Paola Catalano, and Federica Zavaroni

Palaeopathology is a branch of knowledge that studies the diseases of the ancient populations through the observation and examination of the pathological signs detected in the archaeological human remains, generally bone finds. The study of the pathological alterations is also relevant in the anthropological field, because it can indirectly give information on the ancient populations' lifestyle, environment and work and their main hazards.

The understanding and evaluation of palaeopathological data strictly depends on the differential diagnosis of the disease found in the human skeletal samples.

The palaeopathological analysis faces many limitations: first of all, the unavailability of soft tissues, organs, cells, blood and body fluids: the skeleton is only a part of the human body and may not show any trace of the disease affecting the subject during life. Secondly, many different pathologies can affect the bones similarly, which makes the identification of harmful evidence even more difficult. Joint modifications that may first appear as resulting from osteoarthritis, might have other causes instead: traumas, osteomyelitis, gout, haemophilia, psoriasis. A tibial lesion, showing a syphilis-like pattern may well be osteomyelitis due to *Staphylococcus Aureus*, Paget's disease or else [107].

Even a simple periodontal disease, with alveolar retraction, can be the consequence of diet deficiencies, as well as the direct result of poor hygiene [108]. Moreover, many bones can show hypostosis and/or hyperostosis variations (incomplete, failed or excessive ossification) or segment proportion variations: if the morphological differences are mild and do not alter the normal function of an organ, they belong to the wide category of the anatomical variants with little or no pathological relevance [109].

1.3.1 Methods Used in the Examination of the Skeletal Lesions

The first evidence of a disease is shown by a variation in the normal skeletal anatomy; this modification can be an abnormal density, size or shape of the bone, and/or an abnormal formation or destruction of the bone [107]. In human archaeological remains, some of these processes may be either the outcome of *post-mortem* changes (pseudo-pathologies) occurring in the sepulchral environment, or a consequence of problems during and after the excavation, and must not be confused with real pathological processes. Biotic (fungi, bacteria, insects, rodents, plants with their root system) and abiotic (water and sun exposure, ground pH) environmental factors, individual factors (different bone preservation in the same subject or in different subjects), and cultural factors (type of burial and funerary habits) can have significant effects on the state of preservation of human bones [110]. Water and soil can determine the development of concretions on the bone surface that might be confused with reactive modifications of the periosteum; erosive lesions due to fungi might resemble alterations due to osteoclastic activity, and the soil may also be responsible for bone deformation. Frequent *post-mortem* fractures are due to the soil's pressure above the deposition, or to an improper handling of the skeletal remains during and after the excavation. It is therefore of utter importance that experts distinguish between the *ante-* and *peri-mortem* fractures and the *post-mortem* damage. In *ante-mortem* destructive processes, the edges are paler and generally smooth and rounded, and signs of osteoblastic repairing may be present; on the other hand, *post-mortem* lesions are characterized by ragged and irregular edges, with no difference in colour with the other parts of the bone. Once the lesion has been identified as *ante-mortem*, the cause of the abnormality is retraced through the bones' macroscopic examination, the X-ray and electronic microscope examination, and, if possible, the chemical analysis.

The macroscopic observation is generally the first procedure used in the examination of skeletal remains. The first step is to give the most accurate description of the detected alteration, paying attention, as Ortner and Putschar advise [111], to use a clear terminology, to identify the correct location and distribution, and to give a descriptive summary of the abnormal bone morphology.

One example is the word "periostitis", commonly used in palaeopathological literature to define the presence of a bone fusiform hypertrophy [112] affecting the periosteum, which implies an inflammatory process. Since proliferative bone reactions can be caused by a variety of conditions different from inflammation, and the bone macroscopic analysis may not reveal changes in the cortex and/or in the endosteum, a more appropriate word is periostosis. This definition indicates a periosteum hypertrophy without specifying an unsubstantiated cause.

The essential steps of the diagnostic analysis are the cataloguing of the skeletal bones, the description, the location and distribution of the lesions of the subject presenting pathological alterations.

The descriptive analysis has to take into account: if there is only one abnormality with a single pathology focus, if it is bilateral and multifocal, if the alterations are randomly distributed in the skeleton. Moreover, an abnormal reduction of the bone mass in the whole skeleton (even if in different ways) and a local or general modification of the bone size may be present.

Another important consideration to bear in mind is that morbid processes preferentially affect specific bones, or groups of bones, with characteristic locations. Functionally speaking, the skeleton can be divided into axial skeleton (skull, mandible, rachis, ribs and sternum) and appendicular skeleton (pectoral girdles, upper limbs, pelvic girdle, lower limbs). From mid childhood onwards, the axial skeleton is the primary site of blood formation from the marrow, while the appendicular one is the site of fat storage; in skeletal diseases these physiological peculiarities are associated to different patterns of bone involvement and can help the differential diagnosis.

1.3.1.1 Radiological Study of Skeletal Lesions

The imaging techniques applied to bone remains (X-rays and CT) are useful tools in the examination of palaeopathological skeletals and should systematically be employed in the evaluation of the different cases. These techniques, based on differential X-ray absorption depending on tissue density, allow an extremely good analysis of the bone's shape and structure, as well as of the joints' surface. The view can be an orthogonal, oblique and axial view, depending on the need [113, 114]. In addition to the macroscopic evaluation, X-rays examine the bone appearance, its grade of calcification, and structure. If compared with the others, these procedures have an advantage: they are not destructive, and can be used before applying chemical or histological methods. The main information obtained from X examination is the bone tissue involvement and the bone density pattern in the affected area and in its immediate surroundings [115]. For instance, at the macroscopic observation a diaphysis can appear particularly thick with porous tissue and the presence of cloacae. On the contrary, visual examination only does not allow to determine if the medullary space is normal, enlarged or smaller, and the presence of alterations in the cortex. So the imaging techniques are essential to confirm the existence and specify the nature of a bone or joint lesion.

1.3.1.2 Molecular Analysis

There are several types of pathologies identified in the ancient material, and they often do not directly involve the human DNA, but rather the parasites' genetic material. The first pathogenic DNA identified in ancient samples was the *Mycobacterium tuberculosis* [116], soon followed by the *Mycobacterium leprae* [117]. This research has often involved documented epidemic cases, in which the pathogenic microorganisms could have had a crucial role in the pathogenesis [118]. If the preservation and persistence of an ancient bacterial DNA can appear controversial [119], different studies have demonstrated how microorganisms can set up a series of mechanisms which allow them to survive in sub-optimal living conditions, maintaining their genetic material's firmness. Several studies deal with this evidence, among them the analysis of an Israeli grave dated I century A. D.

[120] that represents the first burial, with a proved dating, of an individual suffering from tuberculosis and leprosy, identified at a molecular level. As for the ancient remains, the molecular study has also been useful for the pathogens' molecular identification in archaeological evidence with indefinite palaeopathological diagnosis. In Butrint, an Albanian little town (tenth to thirteenth century A.D.), the anthropological analysis had highlighted round osteolytic lesions on the thoracic and lumbar vertebrae consistent with various pathologies such as tuberculosis or brucellosis, a pathology from the *Brucella sp.* bacterium. The genetic screening on these etiologic agents has allowed identifying the genetic material of *Brucella sp.,* a bacterium easily transmitted with man–cattle contact. This observation has confirmed brucellosis as endemic in the area since the Middle Ages [121]. Finally the whole genome of the *Yersinia pestis* bacterium, isolated from skeletal remains belonging to subjects died during the Plague in 1300 [122], has been lately examined. This research has that there have not been any significant changes in the bacterial sequence if compared with the modern pathogen, which did not explain the reason why the Black Death was so aggressive and virulent in 1300. This epidemic had its onset in Europe in 1347, maybe coming from Asia, and quickly spread over the whole European continent, obliging the governments to set specific burial areas for the numerous deaths. It is from one of these burial areas that the dental elements have been taken as samples to draw the DNA. By a methodological selection of the bacterail genome we managed to ignore the human genetic material and of the environmental contaminants (such as other bacterial forms in the soil) to sequence the whole *Y. pestis* genome, through NGS methods. Without any significant differences among the bacterial strains, the genome analysis has therefore proved that the extreme severity of the Black Death could be ascribed to the epidemiological–environmental conditions of that period [123].

As well as bacteria, some parasites can also be identified through their genetic material preserved during time. Indeed, we are often not only interested in identifying the effects of some parasitic diseases on mummified bodies, but in recovering and analysing the genetic material pertinent to the parasitic agents. One of the pioneering article on the presence of pathologies caused by parasites described Chagas disease, caused by *Trypanosoma sp*., identified by the analysis of the cardiac lesions in mummies from Atacama desert [124]. Since the end of the 1990s a series of studies have begun to identify and isolate *Trypanosomacruzi* DNA, starting from 4000-year-old Peruvian mummies [125]. Further studies have led to various publications on the DNA isolation regarding the parasite even in 9000-year-old Chinchorr mummies [126], which have allowed to identify that Chagas disease was present in pre-Columbian societies and that maybe the prehistoric human groups were in touch with the parasite in different ways [127]. Finally another class of pathologies can be highlighted by the DNA study: tumours. The analysis of the mummified remains belonging to King Ferrante I of Aragon [128] is an example of this use. In this case the mummified body's dissection highlighted a pelvic neoplastic mass. The molecular analysis of ancient tumours gives the precious chance to evaluate the history of neoplasies and compare them to genetic alterations, to lifestyle and environmental risk factors. Because of the limited number of available samples for soft tissue tumours, the case of a King, with his life vivisected in detail by coeval chronicle, is an excellent sample to investigate the role of exogenous elements in the development of carcinogenesis. From a molecular point of view the development of a tumour is connected to the onset of mutations in genes called proto-oncogenes, often linked to the cellular cycle functions. In particular, the proto-oncogenes *K-ras*, especially related to colorectal tumours, if "activated" by mutations [129], and *BRAF* gene, mutated in a wide range of tumoural expressions [130] have been analysed. The achieved findings fitting a mutational pattern in *K-Ras* gene, also implies a mutual exclusion of the mutations in BRAF in colorectal tumours, representing independent elements in the colon carcinogenesis [131].

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