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ARCHEOHANDI: PROTOCOL FOR A NATIONAL DISABILITIES DATABASE IN ARCHAEOLOGY IN FRANCE

ARCHEOHANDI: PROTOCOLO PARA UNA BASE DE DATOS NACIONAL SOBRE DISCAPACIDADES EN ARQUEOLOGÍA EN FRANCIA

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Highlights:

- The archaeology of disability is a recent and little-known field in France, despite the common association between paleopathology, funerary archaeology and osteoarchaeology.
- The Archeohandi database was created to study disabilities and disabling pathologies in France.
- These initial data open up a wide range of research prospects in osteoarchaeology, as well as possibilities for combining them with other study areas, such as virtual reality.

Abstract:

The archaeology of disability is a relatively recent and little-known approach in France. While the study of palaeopathology now goes hand in hand with funerary archaeology and osteoarchaeology, the French study of disabilities and disabling pathologies remains marginal and unevenly treated, depending on location, chronology and researcher's interest. This paper focuses on highlighting the compatibility between this new research area, the obligations of osteoarchaeology, and the benefits of developing a national, diachronic, and interdisciplinary study. A database is designed within an interpretive, consensual framework, that can be adapted to overcome limitations and promote open-minded research on the care of the disabled in their own communities. A preliminary category selection of disabling pathologies has been made. These are trepanation, completely edentulous and/or compensating denture, neuronal impairment, severe scoliosis, Paget's

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disease, Diffuse Idiopathic Skeletal Hyperostosis (DISH), rickets, dwarfism, infectious diseases, unreduced fracture, amputation, severe degenerative disease and others. This list has been critically reviewed by experts in the field; it will evolve in a somewhat Darwinian fashion. Our database is hosted on the Huma-Num platform, with a management interface and quick access based on multiple tabs. The data includes information about archaeological operations, subjects, and pathologies; it is complemented by pictorial data stored on the Nakala platform. The development involved creating a prototype using HTML, CSS, JavaScript, SQL, and PHP, with features to display, add, modify, and delete operations and subjects. Enhancements have been made, including search optimization, charts, and the ability to export data in CSV format. The database, whose administrative interface can be accessed at archeohandi.huma-num.fr, contains so far 211 existing operations with a total of 1232 registered subjects spread throughout metropolitan France. These initial data reveal numerous research perspectives in osteoarchaeology that can be combined with other research topics, such as virtual reality.

Keywords: disability; osteoarchaeology; database; palaeopathology; preventive archaeology

Resumen:

La arqueología de la discapacidad es un enfoque relativamente reciente y poco conocido en Francia. Mientras que el estudio de la paleopatología va hoy de la mano de la arqueología funeraria y la osteoarqueología, el estudio francés de las discapacidades y de las patologías discapacitantes sigue siendo marginal y tratado de forma desigual, según la ubicación, la cronología y el interés de los investigadores. El propósito de este artículo es resaltar la compatibilidad entre esta nueva área de investigación, las obligaciones de la osteoarqueología y los beneficios de desarrollar un estudio nacional, diacrónico e interdisciplinar. Se diseña una base de datos dentro de un marco interpretativo y consensuado, que puede adaptarse para superar las limitaciones y promover una investigación abierta sobre el cuidado de los discapacitados en sus propias comunidades. Se ha realizado una primera selección de categorías de patologías incapacitantes. Estas son trepanación, dentadura postiza completamente edéntula y/o compensadora, deterioro neuronal, escoliosis grave, enfermedad de Paget, hiperostosis esquelética idiopática difusa (DISH), raquitismo, enanismo, enfermedades infecciosas, fractura no reducida, amputación, enfermedades degenerativas graves y otras. Esta lista ha sido revisada críticamente por expertos en la materia y evolucionará de una manera un tanto darwiniana. Nuestra base de datos está alojada en la plataforma Huma-Num, con una interfaz de gestión y acceso rápido basado en múltiples pestañas. Los datos incluyen información sobre operaciones arqueológicas, temas, patologías y se complementan con datos pictóricos almacenados en la plataforma Nakala. El desarrollo implicó la creación de un prototipo usando HTML, CSS, JavaScript, SQL y PHP, con funciones para mostrar, agregar, modificar y eliminar operaciones y temas. Se han realizado mejoras, incluida la optimización de búsqueda, gráficos y la capacidad de exportar datos en formato CSV. La base de datos, a cuya interfaz administrativa se puede acceder en archeohandi.huma-num.fr, contiene hasta ahora 211 operaciones existentes con un total de 1.232 sujetos registrados repartidos por toda Francia metropolitana. Estos datos iniciales revelan numerosas perspectivas de investigación en osteoarqueología que pueden combinarse con otros temas de investigación, como la realidad virtual.

Keywords: discapacidad; osteoarqueología; base de datos; paleopatología; arqueología preventiva

1. Introduction

The concept of disability can be perceived as both a physical condition and a contemporary concept stemming from social construction. The Centers for Disease Control and Prevention (CDC) propose the following interesting definition (Manganello, 2022): "A disability is any condition of the body or mind (impairment) that makes it more difficult for the person with the condition to do certain activities (activity limitation) and to interact with the world around them (participation restriction)." It functions as an established analytical framework for legally evaluating the capacity of individuals with impairments to engage in communal life. The understanding of disability not only varies across different societies but also evolves over time within each society. While the legal definition of disability may not precisely identify the palaeopathological diagnoses made by archaeo-anthropologists, it does provide a foundation for directing our research towards the concept of impairment, which fundamentally underpins our methodology.

Since this was a broad survey, we had to ask about the main categories of disabilities and their consequences on the bones of the subject in question. They were defined by the main French specialized associations (APF: Association of Paralysed in France (Barbier et al., 2010), ADAPEI: Association for the Support Parents of Children with Behavioural Disorders (Benazet, 2009), CCAH: National Committee for the Coordination of Action Handicap (Gevrey, 1982), and international organisations (WHO: World Health Organization (Lee, 2008; Beigbeder, 2015)). They are described below in descending order of their percentage of the currently disabled world population.

- *Disability-related diseases* (48%): Through their effects on the body, they can cause disability and develop over time. These include respiratory, digestive and infectious diseases (e.g., pneumonia, Crohn's disease).
- *Psychological disability* (20%): It is defined by the presence of mental, affective and emotional disorders without impairment of intellectual functioning (e.g., schizophrenia, bipolar disorder, hypochondriasis).
- *Intellectual disability* (15%): This is an impairment of mental and intellectual functions that leads to difficulties in thinking, understanding and conceptualization, which automatically leads to expression and communication problems in those affected (e.g., autism, Down syndrome, multiple disabilities).

- *Motor disability* (13%): It is characterized by a person's limited ability to move around, make gestures, or move certain limbs. Motor impairment may be partial or complete, temporary or incurable, depending on the cause (e.g., paralysis, amputation, cerebral palsy, spina bifida, and myopathy).
- *Sensory Impairment* (4%): This family refers to difficulties related to one or more senses that almost always result in communication problems. A distinction is made between visual impairments (e.g., blindness and low vision, amblyopia, achromatopsia) and hearing impairments, which refer to partial (hearing loss) or complete loss of hearing. Sensory impairment can sometimes also lead to speech problems (e.g., deafness).

It is impossible to reconcile archaeo-anthropological reality with the completeness of this list, since certain disabilities, such as sensory, mental, or psychological, defy any attempt at recognition on the bone. Certainly, there are some very specific cases, such as the still unique specimen with Down syndrome, dated to the end of the 5th century and discovered in Saint-Jean des Vignes (Saône-et-Loire, France) (Rivollat et al., 2014).

While chronic infectious diseases can impair bodily functions by limiting a person's physical abilities, it is often difficult to determine whether or not this disability –and the associated sequelae– are due to the identified infection. Therefore, in our approach, only individuals with established signs of an infectious disease that can be diagnosed with relative certainty are considered to have a disability, as the symptoms identified in current patients often cause impairment. Similarly, advanced technologies allow for more refined diagnoses, such as the examinations of the skeleton of Qafzeh's child, who was accompanied in death by deer antlers placed on his torso by his close relatives. In 2014, a high-precision 3D scan of the inside of his skull revealed that the injury to the bone was much more invasive and resulted in significant growth retardation and irreversible neurological damage (Coqueugniot et al., 2014). It is also important not to systematically establish links between observed skeletal alterations and the presumed level of functional disturbance, as numerous clinical studies demonstrate that there is no correlation between the extent of osteoarticular manifestations detected by imaging, the intensity of symptoms experienced and the importance of functional repercussions: major skeletal alterations may not give rise to significant disability, while minimal alterations may be associated with considerable functional limitations (Sakellariou, 2017).

Since the first articles on databases and archaeology (Ginouvès & Guimier-Sorbets, 1979; Cheetham & Haigh, 1992; Richards, 1998), the number and thematic diversity of these databases have increased considerably (Gattiglia, 2015; McCoy, 2017; Colleter et al., 2020). Their overarching goal is to enable the archiving, access, integration, and use of inherently disparate archaeological datasets (Kintigh, 2006), but the subject is very broad. Outside France, the international literature mentions some collaborative databases for disabled individuals found during excavations (Wilson et al., 2017), so we wanted to develop one for French cases. Over a decade ago, Lorna Tilley (Tilley, 2013; Tilley, 2015) proposed a model of bioarchaeology of care for individuals with disabilities in the past, which partially inspired our database project. This theoretical model encompasses all bioarchaeological and paleoanthropological research on health care and disability assessment in past communities, based on the analysis of skeletal human remains. This field has aroused considerable interest in bioarchaeology and paleopathology (Waldron, 2009; Waldron, 2020) in particular to classify diseases (Üstün, 2001; Üstün, 2010; Ortner, 2003; Buikstra, 2019). A recent symposium was organized as part of the 2023 meeting of the Paleopathology Association (Jankauskas & Piombino-Mascali, 2022). Based on this potential data, 3D (Matczak et al., 2022) simulations and virtual reality tools for studying disabled individuals from the past have only been infrequently mentioned in the literature. A reflection could be done on this topic as well. Our approach aims to identify disabling diseases that occurred at specific time periods in the past, ranging from the Neolithic era to the contemporary period, categorize them, and even verify diagnoses before addressing them comprehensively.

2. Methods

2.1. Selected disabling diseases

Lorna Tilley's work holds significant importance in this field, as the author has not only introduced an evaluation method for the care index (Tilley & Cameron, 2014), but has also established a decision-making approach for the bioarchaeological evaluation of disability severity. This approach has a broader scope than ours in its current state, but it serves as a strong source of inspiration for the evolution of our project. Our approach leads to an initial binary treatment of the subject, i.e., disabled or not. From a purely practical point of view in many countries, access to rights, services and specific accommodations for people with disabilities is determined by a binary classification. This distinction is often required to ensure equality of opportunity and social inclusion by providing appropriate accommodation. Binary classification can also be used to allocate available resources fairly. For example, in the healthcare field, it can help determine the distribution of medical services, financial aid or rehabilitation programs according to the specific needs of people with disabilities. Binary categorization facilitates data collection and research on people with disabilities. It makes it possible to measure prevalence, trends and disparities in disability. The observation, the possible characterization, the compensation, and the evaluation of the consequences will prevail as the "lowest common denominator" that applies to all anthropological series, regardless of the period or area considered. Based on the definitions and objectives, the following list of disabling diseases could be established. The order of the pathologies presented here is the sequence in which they emerged during our brainstorming sessions for designing the database. Based on our initial knowledge, this order did indeed align with the relative frequency of these pathologies, considering the first few known cases in France. It may seem adventurous, and is largely questionable. We have submitted it to experts in the field, who have made a number of criticisms, to which we will return later in the discussion section. But it is a first step that can be modified and/or completed in the future as the database grows. The inclusion criteria could have been much stricter, but our selection approach is initially empirical, generalist and Darwinist, and should ultimately aim for greater precision. In this section, we used the references listed below to assess the biological functionality of individuals.

2.2. Trepanation

The reason we mention it first is that this is likely the oldest documented extraction procedure (documented for over 14000 years to relieve an injured organ (Beyneix, 2015). Some archaeological readings are simple and straightforward (Fig. 1a), while others are more complicated, as the diagnosis, interpretation, or terminology of trepanations can be problematic (Király et al., 2022; Kis et al., 2022; Petrone et al., 2015; Moghaddam et al., 2015). Thousands of skulls with trepanations have been found around the world, attributed to all periods and cultures: in Europe (Giot, 1949; Barnes & Ortner, 1997; Lorkiewicz et al., 2005; Papagrigorakis et al., 2014), in Asia (Sankhyan & Weber, 2001; Erdal & Erdal, 2011; Beigbeder, 2015; Hobert & Binello, 2017), in North Africa (Collado-Vázques & Carrillo, 2014) and in South America. The most spectacular specimens of these craniotomies undoubtedly come from the European Neolithic, often from collective burials such as that of La Chaussée-Tirancourt (Somme, France), dated between 3200 and 2200 years before our era (Guy et al., 1989). The controversy persists regarding the determination of the origin of disabilities resulting from previous surgical practices, whether they had a therapeutic purpose in addition to treating underlying conditions or were implemented as magical rituals, as discussed in Weber and Wahl's 2006 study (Weber & Wahl, 2006). On one hand, the literature offers a significantly high survival rate, surpassing the 50% threshold (Petrone et al., 2015), thus suggesting that past surgical practitioners played a crucial role in the treatment of injuries involving vital structures, such as blood vessels, meninges, and the brain. This raises the question of whether the surgical procedures themselves directly led to the observed disabilities. On the other hand, the outcome of these surgical interventions remained uncertain, and the functional consequences could have caused severe disabilities such as blindness, severe impairment of the masticatory apparatus, and even irreversible mental and psychomotor disorders (Weber & Czarnetzki, 2001; Slepchenko et al., 2017). It was therefore essential to provide assistance to the disabled patient beyond the period of recovery and restoration. The techniques of trephining and their side effects, which were often harmful to the surviving patients, have not disappeared, and long after the "neurosurgeons of prehistoric times", the most learned physicians of antiquity (Hippocrates, Galen, and Celsus) tried their hand at it (Missios, 2007). Numerous necropolises in the Greco-Roman world provide more or less successful examples of these always-risky procedures (Giraud, 2004). Later in the Middle Ages, when the vital prognosis seemed more favourable for the patients, they still found themselves affected by this intrusive intervention and joined the ranks of the medieval "different", not yet "handicapped", but already "infirmis", in need of care and benefiting from the Christian charity established by the Church (Delattre, 2018). Interpreting osteological criteria to determine whether a subject is considered disabled after trepanning requires in-depth assessment and expertise in paleopathology. For example, if the hole created in the skull is large or located near important areas of the brain, this can lead to neurological complications and functional deficits. Assessment of trepanning healing can also be used to determine whether the subject has developed post-operative complications such as infections or wound healing problems. In summary, we believe that individuals in the past who underwent trepanation due to head injuries, epilepsy, neurological, or psychiatric illnesses may not have been cured of their conditions due to the inadequacy of the treatment and/or the antiquated techniques used, which could have led to medical complications. So we have chosen to include trepanation in our database because of its high prevalence, its tangible evidence, and its impact on quality of life.

Figure 1: Disabling injury inventory: a) Trepaned skull from the early Middle Ages (Saint-Urnel-en- Plomeur, Finistère (Giot, 1949)); b) Maxillary edentulous of an 8th-11th c. subject (Noisy-le-Grand, Seine-Saint- Denis); c) Dental prosthesis of Anne d'Alègre (1565 - 1619) (Laval, Mayenne (Colleter et al., 2023)); d) Subject with spina bifida occulta (Bondy, Île-de-France); e) Subject suffering from scoliosis dating back to the 12th century (Heiteren, Haut-Rhin); f) Adult male with Paget's disease (Aschères-le-Marché, Loiret); g) Adult male with DISH (Bobigny, Hôpital Avicenne, Île-de-France); h) Detail of the lower limbs of a juvenile individual suffering from rickets (Saint-Maurice, Val-de-Marne); i) Male subject from the early Middle Ages suffering from achondroplastic dwarfism (Serris, Les Ruelles, Seine-et-Marne (Blaizot, 2017)); j) Subject suffering from a osteomyelitis variolosa in his childhood (Rennes, Jacobins Convent, Ille-et-Vilaine); k) Non-displaced fracture of the left humerus of a subject from the High Middle Ages (Bondy, Seine-Saint- Denis); l) Neolithic subject with amputation of the left limb (Buthiers-Boulancourt, Seine-et-Marne (Buquet-Marcon et al., 2007)).

2.3. Completely edentulous and/or compensating denture

Completely edentulous dentition (Fig. 1b) defined as a major public health problem on WHO as early as 2003, now affects 2.3% of the world's population and is considered a real disability. The majority of completely edentulous people still do not receive adequate care (implants, prostheses) and sometimes have to be supported with adapted foods that have to be chewed beforehand. This condition, common in archaeological cases, will be a valuable testimony of the best-known incapacity (Delattre, 2018). Especially since it is easily identifiable and can be associated with the discovery of protheses, implants or placeholders. For example, in the 3rd century BC at Le Chêne (Aube, France), an iron rod 23 mm long and 1.85 mm wide was found from the maxillary bone of a woman, inserted at the site of the left central incisor. This piece, originally made of a composite material and of which only the iron rod has been

preserved, could have served as a support for a crown made of another material (bone, ivory or dense wood) (Seguin et al., 2014). In the same way, but a few centuries later, in the 16th century, we can consider the prosthetic incisor made of ivory and gold wire of the Countess of Laval, Anne d'Alègre (Fig. 1c) (Colleter et al., 2011; Colleter et al., 2023). Apart from purely therapeutic considerations, the advanced study of periodontal pathology allows us to propose aesthetic and social motivations for the use of this prosthesis. The speech of disfigured individuals can then be considered tainted (Paré, 1652; Colleter et al., 2023). Edentulism as a source of disability has already been the subject of lively debate (Polzer, 2010; Emami, 2013). Determining the degree of disability of a person who was edentulous in the past can be complex, as it depends on a number of factors. For example, if edentulism is due to untreated dental disease or infection, this may indicate a lack of access to dental care and potentially a greater impact on general health and quality of life. If the edentulism occurred at a young age, there may be greater functional and developmental consequences, as teeth play a crucial role in mastication, speech and facial development.

2.4. Neuronal impairment

This category encompasses instances of multiple fused vertebrae, as observed in conditions such as ankylosing spondylitis, alongside open and/or malformed vertebrae, particularly in the context of spina bifida, a fetal congenital anomaly that arises during the early gestational months (Ferembach, 1963; Bennett, 1973; Cate, Kennedy, & Stevenson, 2002; Mitchell et al., 2004; Armstrong et al., 2013). It is characterized by a defect in the closure of the posterior portion of one or more vertebrae (lack of fusion of the caudal neural tube), leaving the contents of the spinal column (meninges, spinal cord, nerve roots, etc.) exposed and unprotected. It is one of the most common malformations in humans (Mitchell et al., 2004). The consequences of this exposure of the spinal cord or its appendages are numerous and cannot all be considered in our review of disabilities. In case of complete or partial spina bifida, hydrocephalus and muscle paralysis (which may progress to quadriplegia) may to be considered. When evaluating these conditions and adding motor impairment, only spina bifida aperta (about 1 in 1000 live births), which largely exposes the spinal cord, is considered, such as the very disabling pathology that affected the Canon buried in the chapter house of the Augustinian abbey of Saint-Séverin in Château-Landon (Seine-et-Marne, France) in the 14th to 17th centuries. The entire spine and sacrum were wide open, and this very pronounced dehiscence left no doubt about the motor sequelae and the inevitable care of this man, who died at the age of about 70 (Delattre & Sallem, 2007). We need to be vigilant about other cases, as the majority of spina bifida occurrences recorded in palaeopathological studies concern cases of spina bifida occulta (Fig. 1d), which do not cause disability because the spinal cord and meninges are intact.

2.5. Severe scoliosis

Scoliosis is a permanent deviation of the spine caused by a rotation of the vertebrae. It occurs mainly in childhood and adolescence (Weinstein et al., 2008), but may also occur in adulthood (Aebi, 2005). Scoliosis is sometimes the result of disease or deformity, which can be readily seen in old skeletons (Flensborg & Kaufmann., 2012). In scoliosis, the spine is rotated, and its natural curvatures are altered. This disease can lead to gibbosity (a hump-shaped deformity of the upper back). If a person has severe scoliosis, it can lead to significant challenges in terms of mobility, pain, and lung function. In our survey, only the latter forms of scoliosis are considered when recording disabilities. This category, of course, includes all the gibbosities listed and identified as such in many 'burial catalogues' of French excavation reports (Fig. 1e).

2.6. Paget's disease

It is a chronic disease with severe effects on the skeleton due to pathological remodelling of bone tissue, resulting in hypertrophy and brittleness of the bone in these areas. It rarely occurs in individuals younger than 40 years of age and can affect any bone, but the pelvis, femur and skull are most commonly affected (Fig. 1f). Less commonly, leg bones (tibia), spine, clavicle and arm bones (humerus) are affected (Paul Tuck et al., 2017). Numerous old cases have been confirmed, especially from the Middle Ages, such as the 16th-century case discovered in Aschères-le-Marché in the Loiret region of France, which was buried with temporary equipment on the right leg (Pecqueur, 2009). Patients experience worsening bone pain at night, often exacerbated by enlarged bones compressing nerves, resulting in nerve pain, numbness, and weakness in addition to bone pain. Enlargement of cranial bones can affect hearing, leading to deafness, and may cause dizziness if the inner ear is affected. Other associated symptoms include hypertension and heart failure (Arnalich et al., 1984; Anand & Florea, 2001).

2.7. DISH

Diffuse Idiopathic Skeletal Hyperostosis (DISH) is characterized by ossification of the anterior longitudinal ligament of the spine (enthesis) (Newman, 2014). The incidence of DISH is linked to lifestyle, potentially due to different dietary habits (Rogers & Waldron, 2001; Jankauskas, 2003; Waldron, 2009; Miszkiewicz & Cooke, 2019). From a functional point of view, ossification of the thoracic vertebrae limits the mobility of the spine through fusion, which can lead to compression of the sciatic nerves and stiffness in the back or neck. The pain associated with this condition can vary in severity but does not necessarily lead to chronic disability (Kagotani et al., 2015) (Fig. 1g). In the same individuals, hyperostosis is frequently found in other joints, particularly those of the patellae and/or calcaneus. Many cases come from archaeological series, e.g. from the Jacobins convent in Rennes (Brittany, France) (Colleter, 2018). However, DISH is frequently diagnosed incidentally during a radiological examination carried out for other health problems, as many people with this condition have no symptoms at all (Kuperus, 2020). But in cases where DISH involves significant implications, we have decided to consider individuals affected as having a disability.

2.8. Rickets

Rickets is a growth disorder that can be observed at any age during childhood. This manifests as a deficiency in the calcification of cartilage and bones, accompanied by issues affecting the spine, including deformities. It is a

disease, caused by a disorder of vitamin D metabolism (Wharton & Bishop, 2003). It leads to bone deformities with potentially serious consequences such as pulmonary infections and respiratory problems. Rickets, which has been poorly documented in Prehistory and Protohistory, became prevalent during the Roman era, coinciding with urbanization and impoverishment. It affects the entire skeleton, particularly causing disabling lesions in the long bones (deformities and curvature of the lower limbs) and in the extremities (visible swellings in the wrists and ankles) (Thillaud, 1996). Depending on the severity and whether it is associated with other pathologies, rickets compromises the quality of life due to motor impairments and respiratory difficulties related to thoracic deformities. The disability status will depend on the severity of the condition and how it affects the daily life of a person with rickets. As an example, consider the child found in the Protestant cemetery of St-Maurice (Val de Marne, France) (Buquet-Marcon et al., 2007) (Fig. 1h). Rickets caused by pseudo-vitamin D deficiency, linked to a genetic defect in vitamin D metabolism, and hypophosphatemic rickets, also genetic and associated with a problem of phosphate resorption by the kidneys, are less frequent. What is more, vitamin D deficiency rickets generally has no after-effects in adults, as it disappears spontaneously during childhood with increased exposure to sunlight and/or consumption of vitamin D-rich foods. Although other metabolic diseases can also cause significant deficiencies, the study of rickets can provide information dietary habits and access to resources in populations of the past. Its characteristics facilitate recognition and analysis in palaeopathological studies.

2.9. Dwarfism

Dwarfism is characterized by a growth deficiency. Achondroplasia is a form of dwarfism and a genetic disorder that leads to abnormal bone development (Kopits, 1976; Horton et al., 2007; Matczak et al., 2022). The pathology is observable from birth, and today, a clinical examination allows for consideration of the family history. Achondroplasia affects, on average, one child in 15000 births (Rousseau et al., 1994). It leads to abnormal bone development, particularly affecting the long bones, resulting in significant bone fragility, frequent scoliosis, and short stature. Dwarfism is considered a disability due to the physical challenges it presents, such as height restriction, health issues, and social implications, requiring specific adaptations to overcome the encountered obstacles. It is also immediately recognizable and frequently mentioned in palaeopathological studies. In France, it is worth mentioning the achondroplastic dwarf found in the Neolithic corridor tomb of Derrière-les-Près in Ernes (Calvados) (San Juan & Dron, 1997) or in the Carolingian necropolis of Serris-les-Ruelles (Seine-et-Marne) (Blaizot, 2017) (Fig. 1i).

2.10. Infectious diseases

This refers to diseases such as leprosy, syphilis, smallpox, etc. Not all infectious diseases are fatal, but their morbidity is particularly high (Gorbach et al., 2004). If they reach the bone and the patient survives, the infection leaves significant damage and disabling complications (Khurana et al., 2019). The question of the origin of syphilis has occupied many researchers and given rise to numerous scientific debates (Hackett, 1976; Dutour et al., 1994; Powell, 1995). The functional effects of syphilis in terms of disability and social care are still neglected (prescription of special diets (Salesse et al., 2019)). On the skeleton, the disease is characterized by exaggerated periosteal reactions, although these are not the only features of the disease. Smallpox is one of the most deadly infectious diseases for humans, with a mortality rate of about 30%, and was declared eradicated in 1980 by WHO (Thèves et al., 2014). Survivors are immune, but the children who survive suffer unfortunate bone sequelae known as osteomyelitis variolosa (Cockshott & MacGregor, 1958; Darton et al., 2013; Colleter, 2018; Khurana et al., 2019) (Fig. 1j). Osteologic observations of this pox in adults are much rarer and occur as sequelae that deform the affected joints (Jackes, 2004; Darton et al., 2013; Colleter et al., 2019). However, it is almost impossible to diagnose this pathology without deoxyribonucleic acid (DNA) analysis or historical records. These diseases are bilateral, symmetrical and preferentially affect the joints of the upper limbs (Khurana et al., 2019). In addition, leprosy causes severe deformities and disfigurements of the affected anatomical areas of the skeleton, preventing the affected individuals from performing basic activities of daily living such as eating, drinking, reaching, standing, or walking (Ortner, 2003). All these infectious diseases require care and regular treatment of affected subjects by the community.

2.11. Complications of an untreated fracture

Fractures are usually caused by trauma (falls, bumps, blows) (Fazzalari, 2011). Complications of neglected – and especially non-displaced fractures are arthroses which will develop rapidly, fixed deformities with the same risk, accompanied by functional complaints, and pseudarthroses, i.e. fracture sites that behave like joints. Thus, non-displaced fractures are considered a disability due to the physical and functional limitations they cause. They can result in chronic pain, loss of mobility, and inability to perform certain daily tasks, and often require adaptations or additional assistance to maintain independence and quality of life (Judd & Roberts, 1998). They are numerous in archaeology (Fig. 1k) and easily identified, such as the one found in the early medieval necropolis of Bondy (Seine-Saint-Denis, France) (Le Forestier, 2021).

2.12. Amputation

This category includes all amputations resulting from human intervention, whether rudimentary (e.g. disarticulation of an elbow) or surgical, with legible tool marks on the long bones of the upper and/or lower limbs (Kirkup, 2007; Kozakaitė et al., 2022). Only the cases in which the survival of the subject could be established by the presence of bone calcifications or prosthesis in situ in the grave were included in our study (Viva et al., 2021). In this context, it is worth recalling the discovery of the oldest French amputation recorded to date, concerning a Neolithic individual operated on about 4700 years before our era and found in a grave at Buthiers-Boulancourt (Seine-et-Marne) (Buquet-Marcon et al., 2007) (Fig. 1l). The recently published amputation of a young individual from Borneo about 31000 years ago suggests that at least some human gatherer groups in tropical Asia had developed sophisticated medical knowledge and skills long before the transition to Neolithic agriculture (Maloney et al., 2022).

2.13. Severe degenerative disease

Osteoarthrosis lesions are a type of degenerative joint disease commonly found in archaeological skeletons (Tanchev, 2017). They provide valuable information about the progressive age of the subject, the limitations of his daily life and all those resulting from certain activities (Arden & Nevitt, 2006). These are cartilage lesions with lesions that may be present in all components of the joint (synovium). Eburnation (Molnar et al., 2011), considered pathognomonic, corresponds to an area where the destruction of the cartilage has led to a reaction of the subchondral bone: its compaction, which has become polished and smooth like a billiard ball, reflects the light, becoming an articular surface. More common are the presence of osteophytes in the periphery of the joint, changes with irregularities in the contour and a change in the joint surface that has become irregular and interspersed with osteophytes. The final result of osteoarthrosis is ankylosis (fusion causing partial or complete loss of mobility of the joint). We have chosen to add severe rheumatic diseases associated with joint ankyloses (Khudaverdyan et al., 2021; Riccomi et al., 2021) to this category because of the pathological processes and consequences they entail for the affected joints (joint ankylosis, deformity and destruction). Degenerative joint disease and inflammatory joint disease are two types of pathology affecting the joints, but they differ in their origin, underlying mechanisms and clinical manifestations. Degenerative joint diseases, such as osteoarthritis, are mainly caused by the normal wear and tear of joints over time. Factors such as age, obesity, previous joint injuries, joint overuse and genetic factors can contribute to their development (Fusco et al., 2017; Rezuș et al., 2019). Other inflammatory joint diseases, such as rheumatoid arthritis, have an autoimmune origin, where the immune system attacks joint tissues, causing chronic inflammation. The exact causes of these inflammatory diseases are not fully understood, but genetic and environmental factors may be involved.

2.14. Others

Our database has a final registration option reserved for rarer diseases. Agenesis (Alao et al., 2014), for example, the absence of formation of an organ or limb during embryogenesis, can be reported, as well as cognitive disorders or Down syndrome (Epstein, 1989). The latter disease (a chromosomal abnormality in which one of the chromosomes pairs is a triplet) causes intellectual and emotional disorders. Osteological identification of this pathology is almost impossible, except in rare cases that require maximum conservation conditions for bone material and burial (Rivollat et al., 2014). The exceptional conservation of some organic tissues may also address other types of pathology, for example, related to the dysfunction of an organ such as the heart or arthritic (Mokrane et al., 2016; Colleter, 2017; Colleter et al., 2018; Colleter et al., 2021). The conservation of lithiasis may also suggest the presence of incapacitating conditions. Conditions like urinary lithiasis (kidney stones) and vesicular lithiasis (gallstones) can be classified as disabling diseases for several reasons, such as the presence of severe pain, recurrent episodes, the potential for serious complications, limitations on physical activities, and dietary restrictions (Gambaro et al., 2001; Jaskowiec et al., 2017). All these disorders can be grouped under the heading "other".

3. Database and user interface

3.1. Prototyping

Our goal was to capture any case of a disease that interferes with daily life, whether physical or mental, at any point in time. The database and its management interface are hosted on the Huma-Num platform (Tufféry & Augry, 2021), a French research infrastructure for literature, social sciences and digital humanities. It was implemented in 2013 by the French Ministry of Higher Education and Research and is supported by the French National Centre for Scientific Research, Aix-Marseille University, and the Condorcet Campus. It also includes France's participation in the European infrastructures DARIAH (Henrich, & Gradl, 2013) and CLARIN (Witt, 2017). It offers digital services for research programs and operates a network of consortia working on digital humanities topics. Our management interface should provide quick access and ease of use and be based on several tabs: Operations (archaeological), Search, Instructions Manual and Pathologies.

Regarding the functioning, the first entry is the operation defined by the municipality and the department, the code INSEE (Pumain & Riandey, 1986), the end date of the operation, the operator and the administrative number (Patriarche (Chaillou & Thomas, 2007) or the code of the excavation corresponding to the year of the operation), the geographical coordinates of the site obtained by an attached map, and the names of the specialists who worked on the site, in the post-excavation or in the diagnosis of pathology.

The bibliography is open to various sources (reports, videos, articles, etc.). The registration of the subject(s) is generated through automatic numbering, in addition to the field registration level. It is defined by age, gender, group membership, standard or atypical context. The "Comment" field allows contextualization according to the site, the different operations, or the different distinguished groups. The damages are to be ticked off by the type of pathology and by the body area, bearing in mind that several disorders may concern the same individual.

An initial interface was designed to work towards a clear visual goal. This proposal consolidated operations, subject groups, subjects, and disabling impairments on the same 4-level page. All the information was visible at the same time, but the complexity of implementation and of data entry was significant. Based on these initial considerations, a navigation diagram (Fig. 2) and a conceptual data model were proposed. The entry point for navigation is a home page, which provides access to the login/management of the user account, the list of operations, the search for operations, and the instructions for use. When the user arrives at the list of operations, he or she can view the details of an operation, edit it, or view the list of subjects. On the latter list, the user can also view the details of one or edit it.

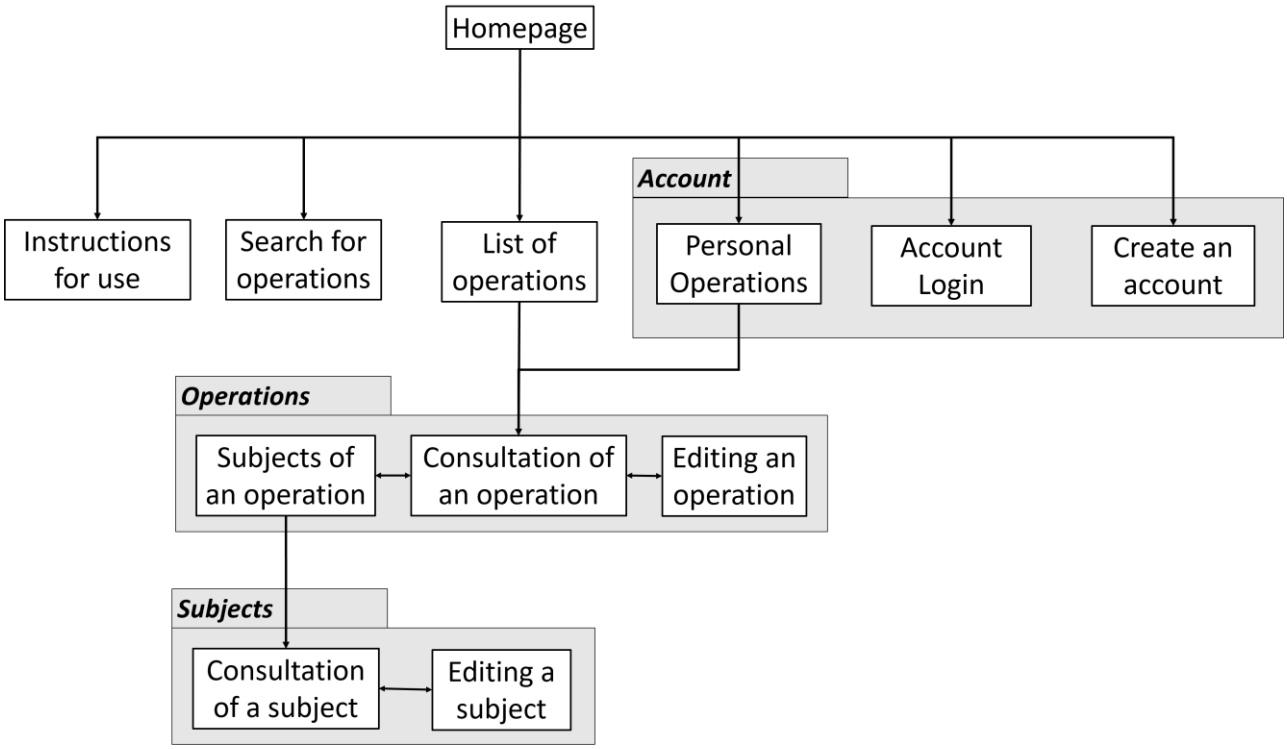


Figure 2: Navigation diagram.

Concerning pictorial representation, we turned to the Nakala platform (Bunel et al., 2022), which is a Huma-Num service designed for researchers, lecturers, and research teams to securely share, publish, and enhance various types of digital data. The platform follows the principles of FAIR (Findable, Accessible, Interoperable, Reusable) data, ensuring easy findability, accessibility, interoperability, and reusability (Joffres et al., 2018). Nakala allows storage, recording, and utilization of diverse documents, such as images, maps and videos, with virtually no capacity limitations. It is open to anyone, requiring registration on Huma-Num and the acquisition of login credentials. The deposited data can be shared with others, granting them necessary permissions. It can be published for open access or included in either public or private collections. In our case, we have chosen to keep it within a private collection until we are ready for the final public release. To facilitate seamless integration, we implemented an “Iconography” entry within the database, referring to pictorial representation and providing direct access to Nakala. This feature allows users to deposit two specific types of documents: photos or plans of the operation, and detailed photos of the subject and their pathologies.

A user manual is available to accompany the deposit process in Nakala within our database. The first step involves creating a record for each visual document submitted and associating it with several metadata. The required metadata includes:

- Author, creation date and title (automatic subject number)
- License (currently Creative Commons Non-Commercial) and date of visibility
- Data type, keywords, and description

Once the record is created, it can be deposited and shared. It is important to note that the author or individuals with sharing permissions can edit the record at any time.

3.2. Development

Following this design phase, we implemented a prototype corresponding to the objective of the input interface during a 2-month period in spring 2021. The languages used were HTML, CSS, JavaScript, SQL and PHP with the two frameworks Bootstrap (Gaikwad & Adkar, 2019) and FuelPHP (Drouyer, 2015). This open-source web framework, written in PHP and implementing the MVC (Model-View-Controller) design pattern (Reenskaug, 2003), is relatively easy to learn and has been extensively used for other research projects in our community (Maguet et al., 2016; Karila-Cohen & Barreau, 2018). The implemented features allowed:

- displaying the list of operations with the option to view their details;
- displaying the list of subjects and their details;
- adding operations and subjects;
- modifying the information of an operation or a subject;
- deleting an operation or a subject.

During the academic year 2021-2022, improvements were made to the code, including identification, creation of functions, comments and documentation. Additionally, unnecessary fields and tables were delated, and functions that were common to multiple pages were consolidated. Autocompletion functions, crucial for our project as they facilitate the search for a commune for a given operation (more than 36000 in France), were also enhanced. The next step involved making the editing of disabled subjects and operations fully functional by precisely adapting the constraints of certain fields. Concerning the management of diagnoses of disabled

subjects, this part was more complex, as mentioned earlier, because a diagnosis is linked to both a subject and a location on their skeleton. The development of a double entry table was therefore necessary.

As far as user accounts are concerned, there are two types:

- an "editor" account has the right to add and modify certain existing operations and subjects. It can only read the information of other operations, unless the owner of the operation has authorised to edit it, by entering the name of the account in the operation in question;
- an "administrator" account has all rights, including creating other accounts.

A search module has been built using the same form as the forms for creating and editing subjects and operations. The results page also displays them in a table with the same format as the table listing all available operations. Query optimisation work has been carried out to avoid results loading too slowly. The creation of the different graphs was done thanks to Highchart (Kuan, 2012; Bartalesi & Meghini, 2017), a Javascript library allowing to make different kinds of customizable graphics. The data stored as JSON (Pezoa et al., 2016) in the HTML page are displayed via:

- pie charts to find out the ratio of individuals with a specific characteristic in a population;
- barplots to find out the number of subjects concerned by a characteristic.

For the export of the data, the choice has been the CSV format, being done via a button using a Javascript function, exploiting the JSON data already used to create the graphs mentioned above.

4. Ethics issue

This study and the construction of the database are the result of considering numerous specific ethical parameters related to the discovery of human remains in an archaeological context (Colleter & Adèle, 2019; Mathieu, 2019). To achieve this, our working group focused on four main themes: result reproducibility, intellectual property, data archiving and transmission, and compliance with the French regulatory framework.

Ensuring result reproducibility is crucial as it guarantees verifiable and validated outcomes by other researchers, thus enhancing the credibility of scientific research. The database primarily contains data derived from the analysis of excavation reports in preventive archaeology. These sources are systematically referenced in the "bibliography" section and dynamically organized using open-source bibliographic management software linked to the database (Zotero). For each case, the storage location and inventory number of the studied human remains are specified, allowing researchers to access the raw data. Whenever available in the excavation reports, illustrations such as photographs and drawings supplement the information, facilitating preliminary assessments without requiring access to the physical collections. These images undergo no computer processing. The anthropobiological methods employed to determine age at death and sex for each subject are clearly indicated. Furthermore, the programming languages used (HTML, CSS, JavaScript, SQL, and PHP) were selected for their robustness, standardization, and traditional usage.

Particular attention is given to respecting intellectual property rights, including proper referencing and attribution of authors, within the database. Therefore, the authors of anthropological and palaeopathological studies that contribute data to the database, as well as the responsible parties of the archaeological operations that generated the data, are consistently acknowledged. Each entry in the database is also linked to its respective author, who is a member of the research program. Ownership information is specified for archival documents, including images, whenever accessible or available. Creative Commons licenses are assigned to both the documents and the database.

The data will eventually be freely accessible to the scientific community, serving the dual purpose of data transmission and archiving. Although the database is still being populated at the time of writing, its entire structure has been designed for open access starting from 2025. The necessary digital services for this accessibility are provided by Huma-Num, a French infrastructure implemented by the Ministry of Higher Education and Research and supported by the French National Centre for Scientific Research (CNRS), Aix-Marseille University, and the Campus Condorcet. Huma-Num offers server infrastructure and utilizes the Nakala platform for data storage, preservation, and exhibition. It plays a crucial role in data preservation and enables open science, making research more accessible, efficient, democratic, and transparent for society. These platforms were deliberately chosen for their infrastructure and information system technologies, facilitating the sharing, dissemination, and stable access to data and documents.

Our research adheres to a strict regulatory framework. The raw sources are obtained from various French preventive archaeology operators, while the investigation is conducted by a joint team from Inrap-CNRS. As a public archaeological service affiliated with the French Ministries of Culture and Higher Education and Research, Inrap is committed to promoting scientific research to enhance our understanding of the past. Additionally, the samples studied come from archaeological excavations mandated by the French State and comply with national laws. In the database, archaeological sites are referenced using their excavation numbers, ensuring state control.

5. Results

The project is named "Archeohandi", which is a combination of the French prefix "archéo", meaning "related to prehistory or a distant period", and "handi", a prefix of "handicap". The diminutive "handi" is often used in France as an abbreviation of "handicapé" or "personne en situation de handicap". It is widely used because of its brevity and familiarity. It should be noted that some people consider this diminutive to be reductive or devaluing, as it can convey an infantilizing or discriminatory connotation. In France, however, the diminutive is easier to pronounce and understand, and therefore easier to disseminate. The pages presented in the following figures are currently in French, and have not yet been translated into English, but translations are planned for the future. On the archeohandi.huma-num.fr page, the user who is not yet logged in arrives at a login page if he or she has clicked on the "Operations" or "Search" button. If they do not yet have an account, they are offered a registration form. By joining the "Archaeology of Disability" working group, he or she

undertakes to respect the ethical framework for the use of the scientific data shared here in a collaborative perspective. With an account, the user accesses the page listing the operations and their nested subjects (Fig. 3). In order to fit our approach into the general principles of reproducible archaeological research (Marwick, 2017), we have hosted the code on GitHub (Jones, 2013) at https://github.com/alex-baiet/archeohandi.

At that point, the user can view the information of all operations and subjects registered in the database (Fig. 4). They are grouped into cartridges, and a tab system allows the user to switch between a given operation and its subjects. The aim here is not to list all the fields, visible in Figs 4 and 5, but to highlight some of their ergonomic and/or scientific characteristics.

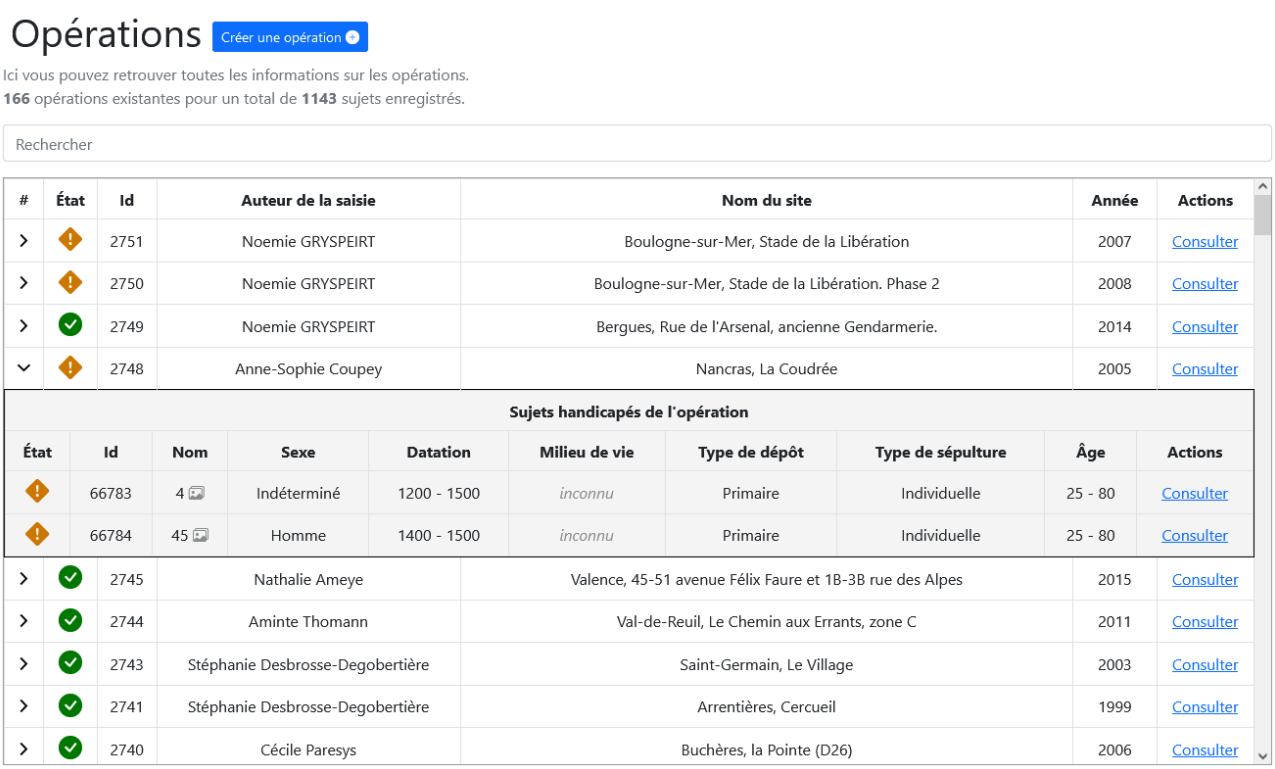


Figure 3: Archeohandi list of operations nesting their sub-lists of subjects.

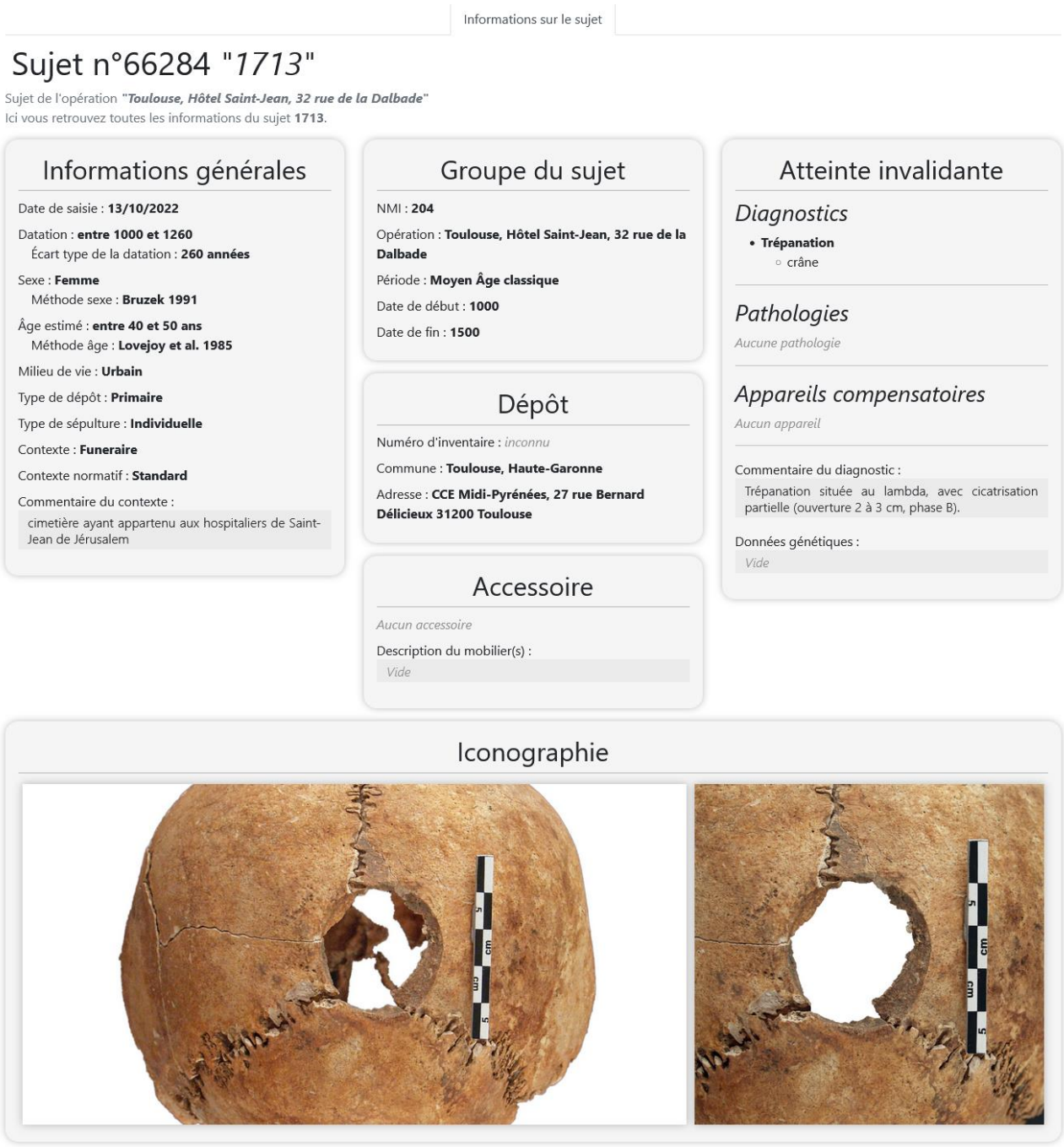
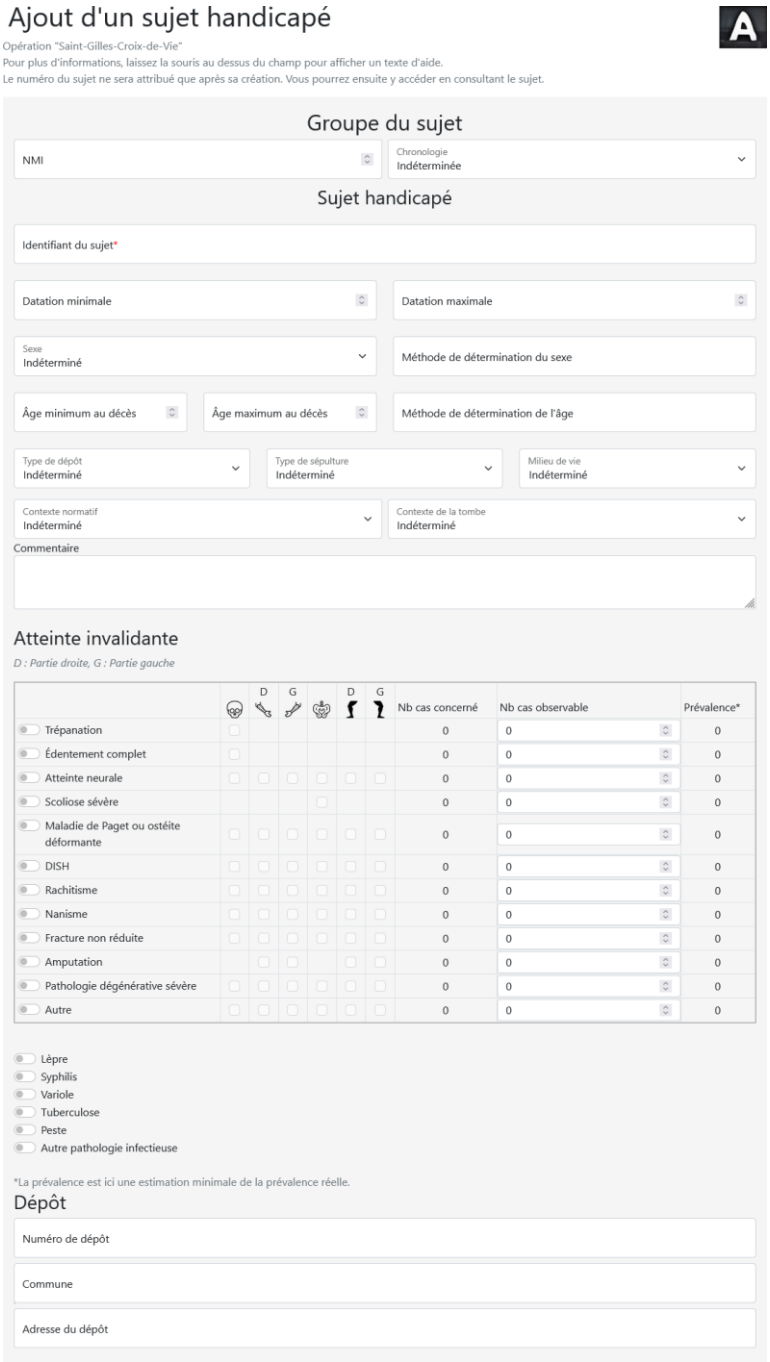


Figure 4: Archeohandi page for viewing information about a subject.

The operation sheet first displays a location map of the site with Leaflet, the free JavaScript library for online mapping (Edler & Vetter, 2019). The subject information includes some elements from the HumanOS application (Colleter et al., 2020). Among them, sex determination (Brůžek, 1991; Brůžek, 2002; Murail et al., 2005; Brůžek et al., 2017) and estimated age of death (Johnston, 1962; Moorrees et al., 1963a; Moorrees et al., 1963b; Stloukal & Hanàkovà, 1978; Kerley & Ubelaker, 1978; Sundick, 1978; Birkner, 1980; Masset, 1982; Ferembach, 1983; Meindl et al., 1985; Webb & Suchey, 1985; Scheuer & Black, 2000; Schmitt, 2005) methods are numerous in our database. Living environments, types of deposits, burials, and contexts are also considered. Potentially found within a set of skeletons from an operation, each subject is assigned to a group of individuals considered able-bodied, based on the minimum number of individuals (MNI) (Kay, 1986). Information about the subject's storage location is also reported in their respective cartridge, particularly to determine its proximity to the operation. For disabling impairments, the concepts of pathologies and diagnoses are visually distinguished from each other, with the latter also clearly identifiable by bone locations.

Regarding the edition of operations (Fig. 5a), the input of location information is well supported by the autocompletion tools mentioned above and the selection of coordinates directly on a leaflet map. If the goal is to retrieve coordinates from an excavation report, for example, which are not in the database system (in this case EPSG4326 long/lat), a link to the tool "The World Coordinate Converter" (Ronzon, 2010) is provided to the user. Multiple edits of anthropologists, palaeopathologists,

authorized accounts, etc., are made on the fly using ergonomic add and delete buttons. After entering the MNI and the chronology of a group, it is again possible to add several subjects on the fly. Due to the large number of fields related to them, their edition is more complex than that of the operations. For disabling impairments in particular, a large table of checkboxes corresponding to their locations and numerical inputs seemed to us to be the most ergonomic solution. To avoid errors, the selection of a location, represented by an evocative icon, is only possible if the pathology is activated. Thanks to the numbers of observable cases for each diagnosis, we proposed an automatic calculation of the number of cases involved, which is the number of subjects with the given diagnoses, and of the prevalences (Bruce et al., 2018), considered here as minimum estimates of real prevalences. In the subject edit form, a JavaScript function updates the prevalence and attached data (Fig. 5b).



B

```
let valuePreva = null;
if (observables.value == 0) valuePreva = 1000;
else {
    valuePreva = 1000 * Number(concerned.innerHTML) / Number(observables.value);
    if (valuePreva > 1000) valuePreva = 1000
}

prevalence.innerHTML = Math.round(valuePreva);
```

Figure 5: Archeohandi: a) Head of the page for editing the information of a subject; b) script to update prevalence.

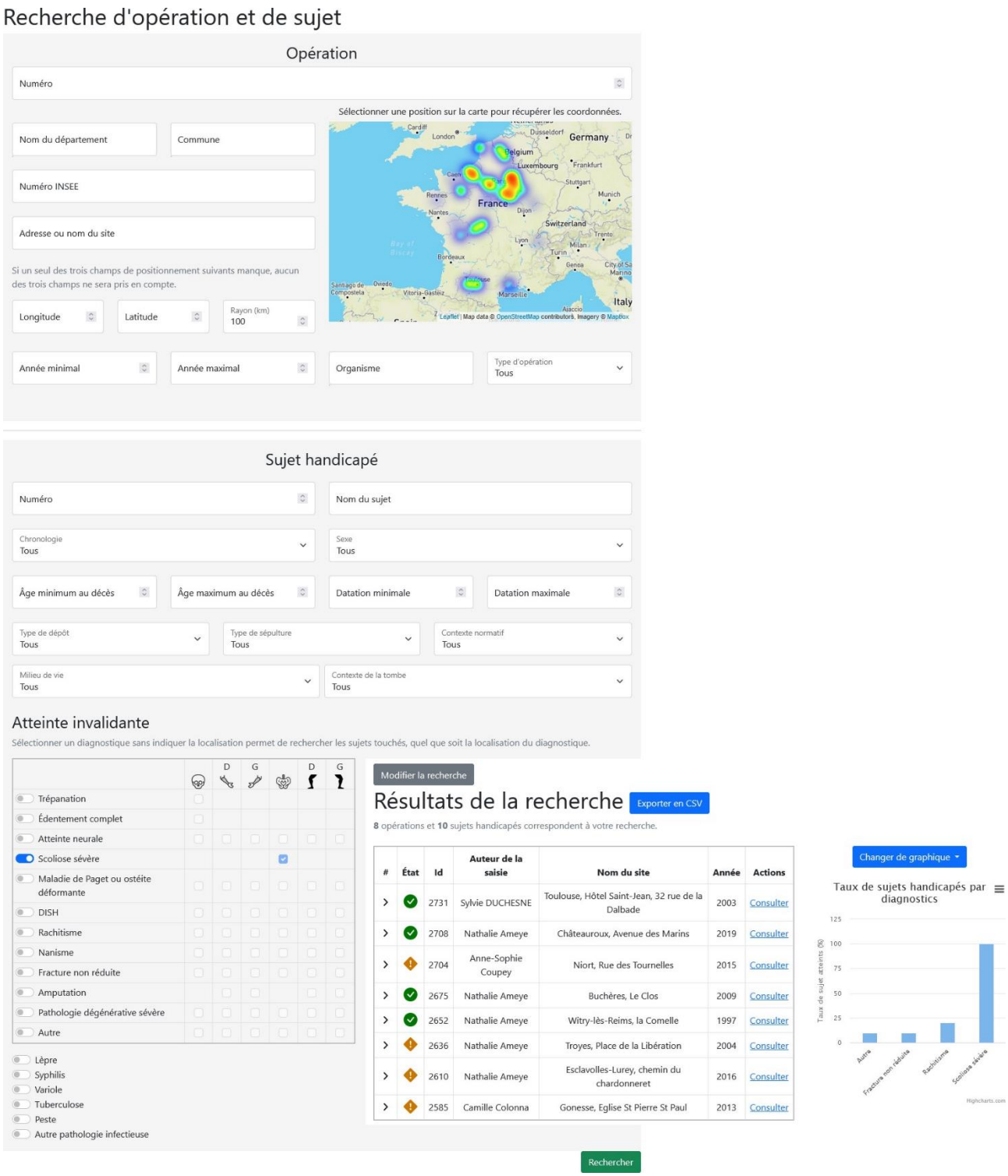


Figure 6: Archeohandi search page for subjects with scoliosis and result of this search.

The search page covers both operations and subjects (Fig. 6). The search for operations is done by their different fields but also by the radius (in kilometres) around a given geographical coordinate. To visualize their current distribution, a heatmap display is proposed to the user. For the subjects, an interface similar to that used for editing localized diagnoses is provided.

The search results (Fig. 6, with a search for individuals with scoliosis) are displayed in the form of the same type of table listing the operations and their nested subjects discussed earlier, along with a bar chart showing the rates of disabled subjects by diagnosis. However, a selection tool allows various other graphs to be displayed on the fly. To offer additional freedom to the user for statistical processing, the CSV export button next to the title generates a file that includes all operations and subjects with all their fields.

At the time of submission of this paper, there are 211 operations with a total of 1232 registered subjects spread over Metropolitan France. These data still need to be verified, both in terms of scientific aspects by peers and in terms of identifying all the actors who contributed to the

data. It is also important to note a disparity among the major French regions concerning our study, which is illustrated at https://archeohandi.huma-num.fr/public/autre/referents. Indeed, some contributors have not yet been able to start data entry due to time constraints. However, since the data entry tool is now functional, they will begin shortly in order to meet the 2025 deadline specified in the perspectives and to which they are committed.

6. Discussion

6.1. The database as a research tool in osteoarchaeology

Regarding scientific research in osteoarchaeology, detailed statistical studies of the data in our database should provide a better understanding of the representation of people with disabilities in the past, as well as the material and human resources that enabled them to live for a certain number of years. As indicated at the beginning of this article, the set of pathologies currently considered as a basis for our work will evolve in the future. For example, experts have recently advised us to add tuberculosis, one of the best-known infectious diseases in palaeopathological archives, specific rheumatic diseases such as rheumatoid arthritis, psoriatic arthritis and spondylarthritis. Initial information uploaded to the database comes exclusively from field reports and the evaluation of pathological findings by archaeologists in the field. A potential evolution of the application would be to include laboratory studies carried out by palaeopathologists, as well as the use of complementary diagnostic techniques such as X-rays, stereomicroscopy, chemical analysis, and many others. It is likely that the raw data from these analyses will show some variability and will not meet minimum requirements for consistency and validity. To remedy this, we will implement standardized protocols specific to each analysis method used. In addition, we will ensure that researchers and analysts are trained and have adequate expertise in the analysis techniques employed. We will also carry out cross-analyses and comparative validations between different analytical methods to assess their consistency. Finally, we will establish regular internal quality controls to assess the accuracy and reliability of the analysis methods used. In terms of the bioarchaeological application of the definition of disability to the archaeological/palaeopathological context, we envisage three general categories of significant impact on people's daily lives: functional limitations, in terms of participation in activities of daily living and social activities. Our approach allows us to move beyond individual cases and to extend the study to populations. Although initially focused on the geographical area of France, these results can be compared to larger surveys conducted at the European/international level or limited to a specific chronological period (Kacki et al., 2023; Micarelli, 2023).

Based on the data, a colloquium on disability and vulnerability will be held in December 2025, featuring national and possibly international presentations over four half-days. This deadline is of great importance because starting from this date, the data will be fully validated by peers, and the database will be open to everyone. Concurrently, through this article, we aim to engage researchers from other French and international institutions to join our group. These researchers would be specialized in theory and practice in the bioarchaeology of care (Tilley, 2015), as well as anthropology and palaeopathology. Furthermore, based on our work, the French National Council for Archaeological Research is considering the establishment of a "Care and Health" axis, which would also incorporate social inequalities and food-related issues (Reddé, 1995).

Despite the current lack of dedicated developer(s), we are committed to continuously improving our database and its management interface. In the short term, we plan to implement improvements such as enabling the search of communes by their INSEE number, displaying a count of subjects by operation, including the possibility of documenting fauna presence in the burial site, presenting various graphs to illustrate the dynamics of data entry over time, and translating the interface into English at least. In the medium term, we will also organize bug-finding and optimization campaigns with users. One of the authors of this article, JBB, lives with a severe form of Type 2 infantile spinal muscular atrophy, which places him in a situation of significant disability. Nevertheless, it is essential to consider the long-term perspective of our project, which would involve integrating individuals affected by the same conditions. This inclusive approach would enable a critical examination of issues such as care hypotheses, benefiting from the firsthand experiences and insights of those directly affected by these pathologies. We have not delved into the textual sources addressing disability in the past as we lack a historian on our team. However, we are also considering the possibility of cross-referencing our archaeological data with historical textual records.

6.2. From database to virtual reality

Furthermore, based on the data produced with our database, we believe that it is possible to extend our research using virtual reality tools. Within the field of archaeological research, the presence of virtual humans (Swartout et al., 2006; Machidon et al., 2018) in simulated environments is still rare. While the visual simulation of these virtual humans remains a complex process, their significance is immense (Barreau et al., 2020), as the study of human being and their activities should remain inseparable from the 3D analysis of their remains in archaeological study (Matczak et al., 2022).

Biological anthropology allows us to deduce many of their physical characteristics (Colleter et al., 2020) and their societal interactions (Barreau & Colleter, 2020). These activities can encompass agriculture, architecture, industry, warfare, funerary practices, and are subject to various physical, climatic, and social constraints. Currently, the study of disability-related issues through 3D simulations primarily focuses on the contemporary world, exploring topics such as mobility within medical environments (Barriuso et al., 2017), work environments (Barriuso et al., 2018), or the design of adapted clothing (Bruniaux et al., 2016; Nakić & Bogović, 2019). However, considering the significant presence of people with disabilities in past populations, we believe that substantial efforts should be made to virtually simulate these individuals within reconstructed 3D archaeological environments.

The use of virtual reality for people with disabilities has been a long-standing topic (Kuhlen & Dohle, 1995). In the field of archaeology and cultural heritage, virtual reality applications are becoming increasingly varied and numerous, often involving virtual humans (Karuzaki et al.,

2021; Gaugne et al., 2022; Sylaiou & Fidas, 2022). In these cases, both the humans of the past and the contemporary users of virtual reality are not virtual themselves. It is the simulated situations that are hypothetical. In relation to our research problem, it is now possible to simulate behaviours of autonomous agents of various appearances (Thiaville et al., 2020), enabling credible interacting with archaeological artefacts described semantically and operating dynamically within a virtual environment.

Virtual and extended reality is also utilized in working with amputees to facilitate their adaptation to prostheses (Resnik et al., 2011; Phelan et al., 2021; Gaballa et al., 2022). In our case, we could well imagine reproducing these experiences with prostheses from the past. It is therefore conceivable that a user within the virtual environment to embody a virtual agent with a disability, allowing for a comprehensive understanding of its coherence and constraints. By enriching virtual archaeological environments with semantic information to describe interactions (Bouville et al., 2015) with virtual compensatory devices and enabling their activation (Castro-García et al., 2015), we can gain deeper insights into daily challenges faced by individuals with disabilities. This can be achieved through the creation of sequences of tasks and complex actions in virtual reality, performed by autonomous agents and directly influenced by contextual factors or specific action (Lécuyer et al., 2020). The quality of these simulations can be evaluated by assessing the sense of embodiment and the user's control of the avatar (Fribourg et al., 2020).

To transform these ideas into reality, we have reached out to the Hybrid research team, which specializing in the field of virtual reality and 3D interaction with virtual environments (Lopez et al., 2014).

7. Conclusion

The diagnostic criteria used in palaeopathology are the result of a combination of clinical research and studies carried out on collections of identified skeletons. With diagnostic confirmation, the aim of the database is to provide information about the archaeological contexts of the subjects, going beyond their disabilities. By sharing the arborescence, the structure and the interfaces of Archeohandi, we aim to propose our diagnostic criteria and encourage related studies on other regions. Indeed, the analysis of excavation reports is time-consuming because of the large amount of recent data, given the development of preventive archaeology. The database currently includes over a thousand disabled subjects recorded in metropolitan France, suggesting promising and numerous research perspectives in osteoarchaeology. These perspectives can also intersect with other research themes, such as vulnerability, inclusion/exclusion, or the exploration of these past experiences through virtual reality.

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