Malaria in Al-Andalus: from written medical sources to a proposal for paleoparasitological study

El paludismo en al-Ándalus: de las fuentes escritas médicas a una propuesta de estudio paleoparasitológico

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Abstract

Malaria, also known as paludism, is a parasitic disease caused by protozoa of the genus *Plasmodium* and transmitted by the female *Anopheles* mosquito. It is notable for its high morbimortality and its importance throughout human history.

References to this parasitosis can be traced in contemporary sources, especially in ancient medical texts. In Al-Andalus, where medical knowledge became influenced by Greco-Latin and Oriental writings, descriptions of symptoms indicate the presence of malaria in populations of the Iberian Peninsula.

This study reviews possible evidence of malaria in medical texts from Al-Andalus and presents a novel proposal for paleoparasitological studies in areas especially susceptible to the presence of these parasites in this culture.

Keywords: malaria, paludism, written sources, Paleoparasitology, Al-Andalus.

Resumen

El paludismo o malaria es una parasitosis causada por protozoos del género *Plasmodium* que se transmite a partir de la picadura de la hembra del mosquito *Anopheles* sp. Destaca por su alta morbimortalidad y su importancia a lo largo de la historia de la humanidad.

Las referencias a esta parasitosis se pueden rastrear a partir de las fuentes antiguas, especialmente en los escritos médicos. En el caso de al-Ándalus, gracias al desarrollo de la medicina, influenciada por fuentes escritas grecolatinas y orientales, se puede inferir la presencia de paludismo a partir de la sintomatología en poblaciones de la península ibérica.

La presente contribución propone un recorrido a través de las posibles atribuciones de paludismo en textos médicos de al-Ándalus, así como una innovadora propuesta de estudio paleoparasitológico en zonas propensas al hallazgo de este parásito en dicho horizonte cultural.

Palabras clave: malaria, paludismo, fuentes escritas, paleoparasitología, al-Ándalus.

1. INTRODUCTION

The medicine developed in Al-Andalus (8th-15th c.) represented a major advance in medical knowledge in the Iberian Peninsula and throughout the known world. At its height, the Arab-Islamic empire extended from Iberia in the West to the Indus Valley in the East and from the

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Pyrenees to the Sahara and the Arabian Peninsula (PEÑA DÍAZ, 2012). Territorial conquests brought the acquisition of knowledge from both Eastern and Western cultures. Accordingly, Greek, Persian, and Hindu writings contributed to medieval Islamic medicine in a process of cultural appropriation common to all empires and civilizations (GUTIÉRREZ AROCA, 2018).

Written sources, especially medical texts, offer evidence on the state of knowledge on diseases in different societies (MITCHELL, 2017), although the lack of preserved manuscripts limits the information available in some settings. In the case of Al-Andalus medicine and its importance, influences from the East and later from the West are manifest in the translated works of some key Islamic physicians, including Avenzoar, Averroes, and Ibn al-Jaṭīb, among others (DE LA PUENTE, 2014).

However, research on medical knowledge in Al-Andalus has paid little attention to diseases caused by parasites, such as malaria. This disease caused by the protozoan genus *Plasmodium* sp. has been associated with a high mortality in the Iberian Peninsula until recent times (FERNÁNDEZ ASTASIO, 2018). The term malaria derives from its historic association with miasmas arising from swamps (in Italian, mal'aria = bad air). The same disease was also known as "paludism" in medieval times because it was associated with swampy areas (in Latin, palus = swamp). The term malaria is used consistently throughout this article.

The objectives of this study were: i) to seek evidence of the presence of malaria in contemporary medical texts, based on descriptions of its signs and symptoms of this parasitosis; ii) to develop a bidirectional methodology that uses the latest advances in the detection of genus *Plasmodium* sp. parasites in ancient materials and exploring their interrelationship with evidence of disease in bone remains, and iii) to propose investigation of the link between malaria in Al-Andalus and the introduction of novel crops such as rice and sugarcane.

2. GENERAL ASPECTS OF MALARIA

2.1. Parasite life cycle

There were estimated to be over 282 million cases of malaria worldwide in 2024, and this disease was considered responsible for around 610,000 deaths in a single year (WORLD HEALTH ORGANIZATION, 2025). Most of these deaths were recorded in Africa (95 %). Among affected populations, the most vulnerable groups were small children, attributable to their immature immune system (75 % of deaths were children aged <5 years in the African regions), and pregnant women, due to their reduced immunity function (WORLD HEALTH ORGANIZATION, 2025).

Malaria is caused by protozoan parasites of the genus *Plasmodium*. Six *Plasmodium* species affect humans: *P. falciparum*, *P. vivax*, *P. malariae*, *P. ovale* (*wallikeri* and *curtisi*) and *P. knowlesi*. The highest complication and mortality rates are associated with *P. falciparum* (BEESON *et alii*, 2002; DEL PRADO *et alii*, 2014). The life cycle of these parasites involves two hosts: humans (asexual replication phase) and mosquitoes of the genus *Anopheles* (sexual replication phase). In this way, humans are infected by the bite of a female mosquito of this genus, which inoculates sporozoites (the infectant form of *Plasmodium*) into the blood (ACHARYA *et alii*, 2017). The sporozoites pass from the dermis to the bloodstream and finally invade hepatic cells. The parasites then undergo a differentiation process in the liver until they reach maturity, when they destroy hepatic cells and return to the blood stream, entering the hemic phase of the infection (WIPASA *et alii*, 2002). These free forms adhere to and invade red blood cells, where the asexual replication phase is initiated and the parasite passes to the trophozoite stage and then to the schizont stage, when fully formed merozoites are ready for release. Next, the parasite ruptures the red blood cells of the host, releasing merozoites (COWMAN *et alii*, 2006) for the infection of new red blood cells and the initiation of a new cycle.

During the red blood cell invasion phase, some parasites differentiate into *Plasmodium* sexual reproduction forms. When an *Anopheles* mosquito bites an individual with malaria it ingests both blood and parasites (BAKER, 2010), initiating the *Plasmodium* sexual reproduction phase in the mosquito and leading to the development of sporozoans ready for inoculation in a new human host.

The red blood cell lysis is generally synchronic, taking place at 48-hour intervals in the case of *P. falciparum*, *P. vivax* and *P. ovale*, and at 72-hour intervals in the case of *P. malariae*. Clinical symptoms of the disease appear after the release of merozoites and are characterized by intermittent febrile episodes. The fever is classified as 'malignant tertian' (*P. falciparum*), 'benign tertian' (*P. vivax* and *P. ovale)*, or 'quartan' (*P. malariae*) according to the time interval between one febrile episode and the next (ROBERTS, JANOVY, 2008). Malaria-like fevers are frequently reported in historical written sources and are commonly used as indicators of the presence of this parasitosis in ancient population (MICHEL *et alii*, 2024; NEWFIELD, 2017; COX, 2002).

2.2. Malaria in human history

Malaria is an ancient disease that has been present in human populations for millennia (LOUFOUMA-MBOUAKA *et alii*, 2021). In common with many other infectious diseases, its impact increased with the development of agriculture and permanent settlements (CARTER, MENDIS, 2002; HEDRICK, 2012).

The introduction of agriculture increased the population density of human settlements and, therefore, the incidence of contagions produced by mosquito bites. A more favorable habitat for mosquito reproduction also resulted from the ecological changes generated by agriculture through the development of water distribution, collection, and storage systems (IJUMBA *et alii*, 2002; ASENSO-OKYERE *et alii*, 2009; DEMISSEW *et alii*, 2020). A high density of *Anopheles* mosquitoes in irrigation systems and stagnant waters allowed malaria vector mosquitoes to be in constant year-round contact with populations.

From a biological perspective, human genes that confer resistance to malaria are a clear example of natural selection operated by pathogenic agents. Thus, there is evidence of a strong correspondence between areas that are or have been endemic of malaria and a high incidence of genetic diseases that affect human red blood cells, including ovalocytosis, thalassemia, falciform cell anemia, and G6PD deficiency (WEATHERALL, 2008; HEDRICK, 2011). Because red blood cells infected by the parasite of malaria by these diseases are not a suitable environment for replication, they provide a certain protection against paludism. The strong evolutionary pressure operated by malaria on populations is one reason why red blood cell diseases are the most frequent genetic diseases in humans (WEATHERALL, CLEGG, 2008).

The first written evidence of malaria in humans dates to 2,700 years ago in China (COX, 2002). There are also possible allusions to its presence in ancient Egypt in the Temple of Dendera (1500 BCE) (HOEPPLI, 1956) and Ebers Papyrus (1500 BCE) (BRYAN, SMITH, 1930). In ancient Greece, Hippocrates (5th-4th c. BCE) clearly described tertian and quartan fevers, while Herodotus (5th c. BCE) reported that fishermen sleep under nets during the summer as a means of avoiding the disease (LÓPEZ ROMÁN, 1990). Malaria is also mentioned in writings from Roman, Asyrian, and Indian cultures (COX, 2002). Of the primary human species of *Plasmodium* that cause malaria only *P. falciparum*, *vivax* and *malariae* are thought to have a deep European history (MICHEL *et alii*, 2024; NEWFIELD, 2017).

The causes of malaria remained unknown until 1880, when the French military physician Alphonse Laverne used optical microscopy to detect the presence of *Plasmodium* in a blood sample from a soldier with typical

febrile symptoms (BOUALAM *et alii*, 2021). Ronald Ross was the first to identify the mosquito as vector of avian malaria in 1887, while Italian researchers reported a decade later that malaria is transmitted by mosquitoes of the genus *Anopheles* (COX, 2010). The discovery of these malaria vectors in Europe led to the implementation of preventive measures, including the draining of stagnant waters and the application of larvicides (ZHAO *et alii*, 2016). Malaria was finally eradicated in Europe in the mid-20th century thanks to national programs and the Global Malaria Eradication Program (194`1050), based on the massive use of DDT (dichloro-diphenyl-trichloroethane) against *Anopheles* mosquito larvae and the distribution of antimalarials to populations in the most affected areas (ZHAO *et alii*, 2016).

3. WRITTEN MEDICAL SOURCES IN AL-ANDALUS

3.1. The development of medicine in Al-Andalus

The development of medicine in Al-Andalus represented an important advance with respect to other contemporary cultures, and the combination of a clear religious vocation with Greco-Latin and Eastern knowledge (SAVAGE-SMITH, 2013) gave rise to a new approach to the study of the individual.

At the time of Muhammad, disease was considered as a series of demons in the Islamic world, imbued in the polytheist tradition that previously dominated the Arabian Peninsula (ÁLVAREZ DE MORALES, 1999, 2006). Rapid Islamic expansion, with territorial conquests in Asia Minor, Syria, and Alexandria, led to the incorporation of Greco-Latin texts and knowledge from Eastern and Hinduist worlds (ÁLVAREZ DE MORALES, MOLINA LÓPEZ, 1999) alongside the religious doctrine that dominated Islamic society (SAVAGE-SMITH, 2013). Translation work was crucial for the circulation of texts, and an especially important role was played by the *Bayt al-Ḥikma* (House of Wisdom) in Baghdad, founded in the 9th c. (CHANDIO, 2021). Greek ideas became increasingly influential, with the dissipation and evolution of disciplines towards a global and holistic understanding, bringing philosophical and theological issues into the formation of physicians (DE LA PUENTE, 2014).

The first Muslims who settled in the Iberian Peninsula during the 8th c. had a marked military character, accounting for the lack of medical writings at the beginning of Al-Andalus (CASTILLA BRAZALES, 1999), when there was a dependence on autochthonous Mozarab authors (DE LA PUENTE, 2014). Medical knowledge began to expand under Abd ar-Rahman II (Emir from 822 to 852) with the arrival in Cordoba of the prominent physician al-Ḥarrānī (CASTILLA BRAZALES, 1999). In the 10th c., the Caliphate of Córdoba became the epicenter of Al-Andalus science, and key authors such as Abulcalsis/al-Zahrawi, Sunprunt, and Ibn Ŷulŷul made important contributions to medical knowledge (DE LA PUENTE, 2014). Despite the subsequent fall of the Caliphate, these investigative efforts and the search for knowledge continued and was even intensified in the *Taifas* (small Muslim kingdoms/principalities) that remained (CASTILLA BRAZALES, 1999).

However, the greatest advances in medical knowledge were achieved in the 12th c., largely attributable to the Al-Andalus physicians of greatest renown at the time: Abu Marwan Abd al-Malik ibn Abil-Ala, known in the West as Avenzoar (1092-1162), and Abu l-Walid Muhammad Ibn Ahmad ibn Rushd, known as Averroes (1126-1198). Several of their writings are preserved, mainly due to their translation and circulation in the East and West, where they became the object of study from the Renaissance period onwards (DE LA PUENTE, 2014).

The 12th century was characterized by political tension and a change from Almoravid to Almohad dominance (DE LA PUENTE, 2014). Convulsions were also caused by battles against Christian populations to the North, with continual frontier changes. The publication of medical works declined in the 13th c., when there was an increase in the translation

of Latin texts (CASTILLA BRAZALES, 1999). The writings of Ibn al-Jaṭīb and Ibn Jātima stand out under the Nasrid dynasty (1232 to 1492), and these two authors from Almeria even developed the pathophysiological concept of multiple organ dysfunction syndrome (HERRERA CARRANZA, 2021).

3.2. Evidence of malaria in medical texts of Al-Andalus

Given the lack of contemporary knowledge on the parasites responsible for malaria, the study of Al-Andalus medical texts focuses on their descriptions of relevant signs and symptoms. The most indicative symptom is intermittent fever with a time cycle compatible with the different *Plasmodium* species responsible for malaria in humans.

There is a limited number of medical texts suggesting the presence of malaria in these populations. However, the works of only a few authors have survived or been translated, and greater evidence may emerge in the future with the translation of a larger number of authors and writings. Knowledge is restricted to a few authors whose great renown led to the assimilation of their writings within the Eastern and Western medical corpus.

To our best knowledge, the first medical author to describe malaria-related symptoms was Avenzoar (1092-1162). He was born in Seville into a renowned family of physicians (Banu Zuhr) and received first-level medical education from an early age, including the study of Greco-Latin texts, and his writings reveal the influence of the works of Galen (DE LA PUENTE, 2014). In accordance with the multidisciplinary approach that was dominant in Al-Andalus, he also underwent religious, legal, and literary education. His writings made an outstanding contribution to medicine, and two of his publications describe fevers that could be caused by malaria. Thus, he refers to a tertian fever in *Kitab al-Iqtisad* (the book of moderation) (THÉODORIDÈS, 1955), and he describes an intermittent tertian fever attributed to the putrefaction of yellow bile in *Kitab al-taysir fi l-mudawat wa-l tadbir* (book that simplifies medication and diet), which has not yet been translated (PEÑA MUÑOZ, GIRÓN IRUESTE, 2005, 2010). As noted above, intermittent tertian fevers are typical symptoms of malaria caused by *falciparum* and *vivax* species. In the 1950s, the Swiss German physician Hoeppli proposed that Avenzoar was familiar with the clinical aspects of malaria, but he did not cite a text to support this proposition (HOEPPLI, 1956).

References to malaria can also be traced in the writings of Averroes (1126-1198), who was born into a prominent family of jurists in Cordoba, where he received an education in grammar and poetry as well as medicine. He was considered one of the most important physicians in Al-Andalus, publishing philosophical and medical texts that were translated into other languages and became recognized in the Western world during the Renaissance (DE LA PUENTE, 2014). Averroes devoted a section of his work *Kitab al-Kulyat fi al-Tibb* (*Book of Generalities of Medicine*) to the healing of quartan fever (CORDERO DEL CAMPILLO, 1980), indicating the application of poultices to the area of the spleen as a possible remedy (VÁZQUEZ DE BENITO, ÁLVAREZ MORALES, 2003). Splenomegaly (spleen swelling) is a typical clinical characteristic of malaria, because the spleen is the organ most involved in the immune response against the parasite and in the elimination of parasitized and/or damaged red blood cells (ENGWERDA *et alii*, 2005; CHAVES *et alii*, 2011; DEL PORTILLO *et alii*, 2012). Quartan fever may also suggest an infection caused by *P. malariae*.

Possible allusions to malaria also appear in the work of physician Ibn al-Jatib (1313-1375), who was born into the Banu Wazirm family in Loja and engaged in various fields of knowledge. In his volume on medicine entitled *Mi'yār al-ijtiyār fī ḏikr al ma'āhid wa-l-diyār* (IBN AL-JATIB, 1977), he referred to fevers in areas of sugarcane cultivation in Salobreña (Granada) (MALPICA CUELLO,

2012). It can be assumed that these fevers are related to malaria because crops that require a high amount of water favors reproduction of the *Anopheles* mosquito (IJUMBA *et alii*, 2002; DILLON *et alii*, 2014). The *Plasmodium* species involved cannot be identified because, unlike the aforementioned authors Ibn al-Jatib did not describe the types of fevers encountered.

4. PALEOPARASITOLOGY IN THE STUDY OF MALARIA

4.1. Study of parasites in ancient material

Paleoparasitology involves the finding and interpretation of parasites in ancient material, either from archeological or paleontological sites (FERREIRA *et alii*, 2014). Combining these findings with the study of human populations can yield a wide spectrum of bioarcheological knowledge on hygienic/sanitary aspects, the presence of domestic and peridomestic animals, migratory routes, and different socioeconomic strategies (LE BAILLY *et alii*, 2021). However, this discipline remains underdeveloped in Spain, with a limited number of published studies, mainly in recent years (see MAICHER *et alii*, 2017; KNORR *et alii*, 2019; LÓPEZ-GIJÓN *et alii*, 2023a, 2024).

Development of this discipline worldwide and advances in rehydration techniques (DUFOUR, LE BAILLY, 2013; ROMERA BARBERA *et alii*, 2020) have revealed a wide range of materials in which parasitological evidence can be obtained. These include the contents of archeological structures such as latrines, cesspits, and pipework, which can be associated with human populations. A direct association of parasites with specific individuals can be detected by the study of parasites in mummified or skeletonized remains (LÓPEZ-GIJÓN *et alii*, 2023b; COPPOLA-BOVE *et alii*, 2024), allowing exploration of relationships between the presence of certain parasites and diseases or diet, among other anthropological issues (LÓPEZ-GIJÓN *et alii*, 2021).

The study of ancient parasites has been improved by technological developments, so that information can now be gathered on their morphology, associated antigens, and DNA. For morphological identification, the basic technique is still transmitted-light bright-field optical microscopy, while screening electron microscopy can also be used. Antigen detection is performed by indirect immunofluorescence using and enzyme-linked immunosorbent assay, while the DNA of parasites is studied by polymerase chain reaction amplification.

Studies of ancient parasites have revealed both endoparasites (within the host) and ectoparasites (on the host surface). Most research to date has been on intestinal helminths, focusing on the dispersion phases developed outside the host (known as geohelminths). This is because their highly resistant shells favor their preservation over long time periods (WHARTON, 1980). Less research interest has been shown in protozoa, despite the considerable information they can offer on ancient populations. Although their study is more challenging, some investigations have been conducted over the past few years on this type of parasite, including *Plasmodium* sp.

4.2. Finding of *Plasmodium* sp. in past populations

Unlike other parasites, *Plasmodium* sp. cannot be morphologically identified under optical microscopy because their structure is not preserved at cellular level. Consequently, one approach to study the presence of malaria has been to identify possible malaria-prone areas based on the presence of skeletal markers that can be related to anemia (GOWLAND, WESTERN, 2012), including *cribra orbitalia* (SMITH-GUZMÁN, 2015) and porotic hyperostosis (SETZER, 2014). However, it is difficult to establish their association with the presence of *Plasmodium* sp. because of the possible multifactorial etiology of these lesions (WALKER *et alii*, 2009; BRICKLEY, 2018; O'DONNELL *et alii*, 2020).

Hence, other methodologies are needed to evidence in a direct manner the presence of *Plasmodium* sp. in past societies. Technological advances achieved over the past few years include immunological techniques, which can be used to detect specific antigens of *Plasmodium* sp., and DNA testing, identifying the parasite from its genetic material (BIANUCCI *et alii*, 2015). Implementation of these technologies has yielded the first direct evidence of malaria in ancient mummified and skeletonized individuals (NERLICH, 2016). Molecular techniques can be used to detect *Plasmodium* spp. in different types of biological materials. They can be applied to samples of tissue (e.g., muscle) from mummified bodies (BIANUCCI *et alii*, 2015) and to different samples obtained from skeletal remains, including spongy bone, the pars petrosa of the temporal bone, and dehydrated matter from tooth pulp chambers (BIANUCCI *et alii*, 2015; MICHEL *et alii*, 2024).

Most studies have been conducted in regions in the Mediterranean basin using immunological (MILLER *et alii*, 1994; RABINO MASSA *et alii*, 2000; BIANUCCI *et alii*, 2008; FORNACIARI *et alii*, 2010a, 2010b; BIANUCCI *et alii*, 2014; AL-KHAFIF *et alii*, 2018; LOUFOUMA-MBOUAKA *et alii*, 2020, 2021) and DNA (TAYLOR *et alii*, 1997; SALLARES, GOMZI, 2001; ZINK *et alii*, 2001; NERLICH *et alii*, 2008; HAWASS *et alii*, 2010; LALREMRUATA *et alii*, 2013; GELABERT *et alii*, 2016; MARCINIAK *et alii*, 2016; LOUFOUMA-MBOUAKA *et alii*, 2021) techniques to identify parasites.

4.3. Proposal for the study of Al-Andalus populations

The study proposal outlined below is motivated by the evidence of malaria in Al-Andalus medical texts and the known presence of the genus *Plasmodium* in Spain, where malaria was endemic until recent times (FERNÁNDEZ ASTASIO, 2018; SAINZ-ELIPE *et alii*, 2010).

In an initial geographic approach, a study will be conducted to identify places that would have featured swamps or standing waters during the Al-Andalus period, allowing *Anopheles* sp. to lay their eggs. Temperatures will also be considered, given that the presence of mosquitoes is more likely in tropical or subtropical than colder regions (BECK-JOHNSON *et alii*, 2013). Economic factors must also be considered, given the relevance to human mosquito exposure of the ecological changes produced by the introduction of novel crops in Al-Andalus, especially rice and sugarcane in monoculture. These plants require flooded or canal irrigation and are responsible for the abundant availability of standing water for the mosquito eggs (IJUMBA *et alii*, 2002).

Rice has been cultivated in the Iberian Peninsula since the 10th c., although its consumption was initially limited to the elite (RIERA MELIS, 2016). Its cultivation in various areas was documented by various Al-Andalus authors, including Ibn Bassāl and al-'Uḏrī (RIERA MELIS, 2016). For instance, climatic and geographic conditions favored the cultivation of rice in the Spanish Levante from the beginning (PERDIGUERO GIL, 2005; BUENO-MARÍ, JIMÉNEZ-PEYDRÓ, 2010; BUENO VERGARA, 2017). Indeed, this region was considered the principal focus of transmission for malaria outbreaks on the Iberian Peninsula during the 18th, 19th, and 20th centuries (ALBEROLA-ROMÁ, BERNABÉ GIL, 1999; MOLINA PRADOS, 2017).

Sugarcane also began to be cultivated in Al-Andalus in the 10th c., becoming part of the diet of the population (MURO, 2017; IBN AL-JATIB, 1977). One sign of its consumption is the increased prevalence of caries in infants (JIMÉNEZ-BROBEIL *et alii*, 2022). It was mainly cultivated in coastal areas of Al-Andalus, where it continues be grown to date (MACHADO SANTIAGO, JIMÉNEZ BAUTISTA, 1995). Unlike in the case of rice-growing areas, sugarcane fields were not regarded as main transmission locations, although evidence of an association between malaria and sugarcane has been observed until very recent dates (FERNÁNDEZ ASTASIO, 2018).

Although no bone markers can be exclusively attributed to malaria, the study of skeletal remains may contribute information on

its possible presence in ancient populations. It is included in this multidisciplinary proposal of study to gather the largest possible body of evidence. It may also allow the individualization of probable malarial infection by the detection of possible cases of anemia-related diseases (e.g., porotic hyperostosis and *cribra orbitalia*) and allow the exploration of their relationship with malaria. To enhance the probability of detecting malaria, skeletal samples will be selected from geographical regions in which historical medical sources describe malaria-like fever, or where past environmental conditions were favorable to the development and persistence of the parasite's vector. Due to the non-specific nature of the bone lesions observed in the macroscopic analysis of skeletal materials, the study will apply molecular techniques. In particular, the DNA analysis has, in recent years, proven to be the most suitable and reliable methodology for investigating malaria in past populations (COPPOLA-BOVE *et alii,* 2024*;* MICHEL *et alii*, 2024). For this reason, following Michel *et alii* (2024), samples of teeth and the petrous portion of the temporal bone will be collected during the macroscopic examination for subsequent DNA analysis. It is planned to study at least 50 individuals from each archaeological site, including individuals of both sexes and all age ranges, following previous work (MICHEL *et alii*, 2024).

5. CONCLUSIONS

The preserved writings of renowned physicians in Al-Andalus include descriptions of the typical symptoms of malaria inhuman. Given the amount of contemporary medical literature that would not have survived to the present day, it is not possible to rule out a greater knowledge of malaria in Al-Andalus.

The introduction of rice and sugarcane cultivation in Al-Andalus produced areas of standing water that favored the development of *Plasmodium* sp. in human populations. The proposed study will therefore focus on sites in Al-Andalus where these monocultures were practiced. In a multidisciplinary approach, anemia-related paleopathological evidence will also be gathered and compared with findings on the presence of malaria. In turn, this work will carry out molecular analyses to corroborate these findings.

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