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A case study of spinal pathology and degenerative joint disease in Udhruh, Jordan

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Abstract: *This study presents an osteobiographical analysis of an adult male buried beneath the floor of a Byzantine church at Udhruh in southern Jordan. Standard macroscopic methods were employed to determine the biological profile and assess pathological lesions. The individual was male aged between 27 and 66 years with an average of 45.6 years old, and 181.4±3.27cm tall. Vertebral fusion between T7 and T11 exhibited left-sided flowing ossification, consistent with diffuse idiopathic skeletal hyperostosis (DISH). Schmorl's nodes and osteophytes were also observed in the spine. Degenerative joint disease (DJD) was identified in the left knee, with accompanying osteophytes and eburnation. Although the spinal lesions are characteristic of DISH, their unusual left-sided distribution may indicate an anatomical variation, such as situs inversus. The observed bone lesions could e.g. suggest obesity or a diet high in protein. However, the unilateral nature of the osteoarthritic (OA) lesions in the knee does not support the hypothesis of obesity. The burial context implies elevated social status—possibly elite rather than clerical—which may, in turn, suggest a protein-rich diet.*

Key words: Byzantine period; DISH; OA; osteobiography

Introduction

The Byzantine period in Jordan is generally considered to have begun in A.D. 324, when Constantine the Great defeated Licinius and gained control of the Eastern Roman Empire. This era lasted until Muslim forces annexed the region in A.D. 634 (Al-Shorman 2004). The spread of Christianity marked the Byzantine period, the construction of churches being key architectural symbols, and the continued prosperity of cities established during the Roman period (Al-Shorman 2004).

One such context is the archaeological site of Udhruh (also spelled Udruh), a small village in southern Jordan (30°19’41”N, 35°35’55”E). It is located approximately 13

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kilometres east of Petra (**Figure 1**). Udhruh was one of the most significant sites in the region. The settlement began in prehistoric times and continued through the Hellenistic, Nabataean, Late Roman, Byzantine, and Islamic periods. As late as the 9th century CE, Udhruh served as the regional centre of the Sharat district. During the Ottoman period, a fort was constructed in the town. Udhruh was eventually abandoned in this era, and the modern village was established in the late 1930s.

Figure 1. Map of Jordan showing Udruh (drawing by Walid Abualhayja).

Located approximately 30 meters south of the Roman fortress, the Byzantine three-nave church at Udhruh lies outside the city walls. At some point, the church was expanded with the addition of two side chapels and several adjoining rooms (Al-Bashaireh et al. 2020). Excavations revealed three graves beneath the church floor, containing the remains of five individuals (**Figure 2**).

Although identifying individuals by name in archaeological contexts is rarely possible, osteological analysis can offer valuable insights into their life histories. By constructing an osteobiography—an individual life narrative based on skeletal evidence—researchers can investigate various aspects of a person's lived experience (Boutin 2022; Hawkey 1998; Hosek & Robb 2019). Such analyses reveal not only basic biological characteristics such as age-at-death and sex, but also information related to health, diet, and activity patterns, offering a more holistic understanding of the individual's past (Byrnes & Muller 2017; Martin et al. 2013; Mays 2021).

Among the individuals buried within the Udhruh basilica, one—designated as Individual 1 from Grave 1—exhibited distinctive skeletal lesions that offer an exceptional opportunity to explore their osteobiography. As such, this study focuses on the life and pathological profile of that individual.

This case study is significant, as osteobiographical analyses from the region remain scarce (Protopapadakis 2025; Sheridan 2017). The location of the grave suggests elevated social status, offering rare insights into the health of local elites.

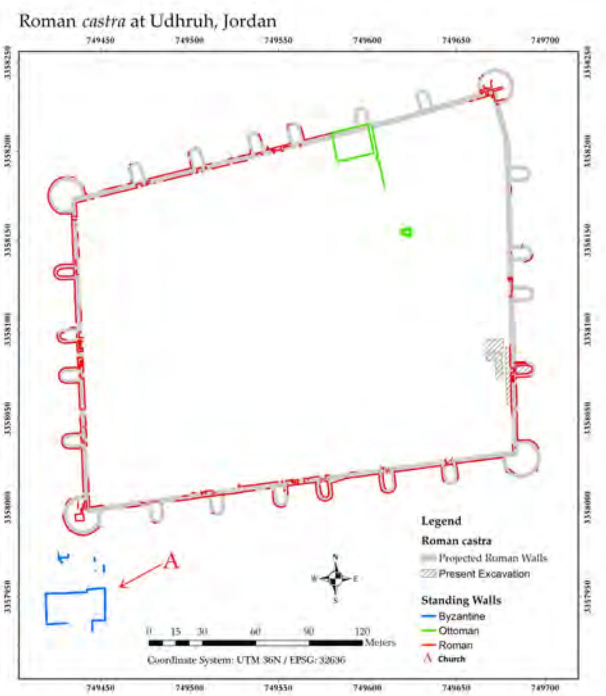

Figure 2. Location of the basilica in Udruh (after Driessen & Abudanah 2019, Figure 1).

Material and methods

As soon as the Jordanian Department of Antiquities heard that a group of grave robbers had unearthed tombs to steal the artifacts, a team headed by Hani Falhat rescued the tombs at the site of Udhruh in 2006. The excavation focused on the central nave of the Byzantine basilica, specifically to the left of the southern main entrance and to the right of the chapels. A test trench was opened, measuring approximately 152–190cm in width and 258–320cm in length.

Grave 1 was the only single burial and contained the remains of an adult individual. In contrast, the other two graves each held the remains of two individuals: one grave contained a male and a female (the male was approximately 27–66 (mean 45.6) and female 26–70 (mean 38.2) years old at the time of death), while the other held the skeletons of two children; the first was 6–10 years old, the second was 7–11 years old based on tooth eruption (AlQahtani et al. 2010; Ubelaker 1999; Krogman 1962). The individual in Grave 1 was laid in an extended supine position, oriented east-west, with the hands crossed over the abdomen. In Grave 2, the two skeletons were interred one above the other. Stratigraphic analysis suggests that the upper individual was buried at a later time.

The individual's age at death and sex were assessed based on the morphology of the pubic symphysis (Brooks & Suchey 1990; Buikstra et al. 1985; Phenice 1969). Stature was estimated using femur length, following the method described by Trotter and Gleser (1952, 1958).

All bones were examined for signs of pathological lesions and bone alteration. Observations were described and documented photographically. A differential diagnosis was conducted following Ortner (2007), using comparative data from both paleopathological (Aufderheide & Rodríguez Martín 2011; Ortner 2003; Waldron 2008) and medical literature (e.g. Lagier 2006; Lee & Kean 2012; Rogers et al. 2004).

Results

Skeleton 1, excavated from Grave 1, belonged to an adult male, estimated to be between 27 and 66 years with a mean of 45.6 years old at the time of death. His stature was approximately 181.4±3.27cm. Almost all parts of the skeleton were well-preserved as shown in **Figure 3**. Examination of the bone surfaces revealed several pathological lesions, which are described below.

Spine lesions

One of the skeleton's most prominent features was the fusion of the thoracic vertebrae from T7 to T11 (**Figure 4**). The fusion was left-sided, exhibiting the characteristic "dripping candle wax" appearance associated with diffuse idiopathic skeletal hyperostosis (DISH). DISH is a systemic condition that is often asymptomatic, characterized

Figure 3. Preservation of the bones of Individual 1. Preserved bones are marked in gray.

by calcification and ossification of ligaments and tendons, predominantly around the spine (Waldron 2008). A typical feature of DISH is continuous ossification along the anterolateral aspect of the thoracic vertebral bodies (Waldron 2008).

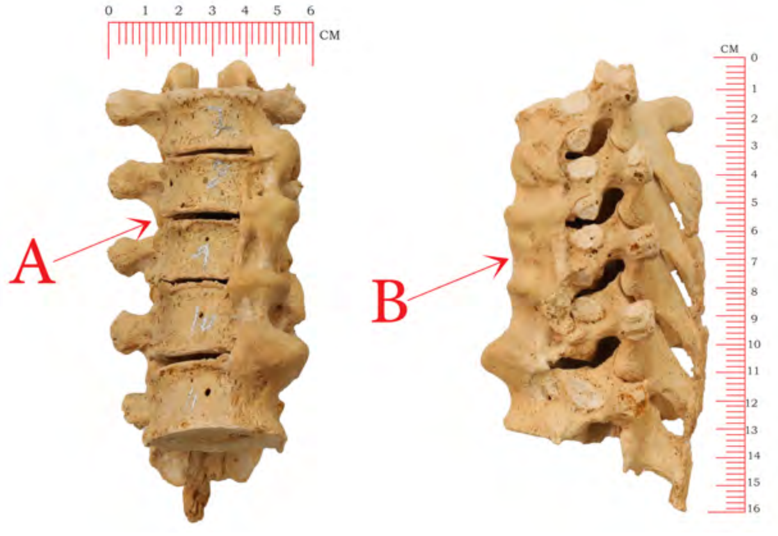

Figure 4. Anterior view of the T7–T11 spine: (A) right side of the vertebral bodies without bone lesions and with preserved intervertebral spaces; (B) left-sided fusion of the spine showing a "dripping candle wax" appearance (photograph by Bilal Hammouri).

However, such ossifications are more commonly seen on the right side of the spine, a pattern likely influenced by the anatomical position of the descending aorta on the left. Waldron (2008) noted that left-sided DISH can occur in individuals with *situs inversus*, a congenital condition in which the thoracic and abdominal organs are mirrored from their normal positions, affecting approximately 1 in 10,000 people (Osarenkhoe 2022), and more common in males (Eitler et al. 2022). In this case, no aortic impression was observed on the right side of the vertebral bodies. DISH is more frequently diagnosed in males and individuals over 65 years of age (Ortner 2003), and it is rarely identified before the age of 40 (Aufderheide & Rodríguez Martín 2011). A hallmark criterion for DISH is the preservation of intervertebral disc height, which is visible in **Figure 4**. The presence of outgrowths from the central third portion of the vertebral body is associated with DISH, in contrast to ankylosing spondylosis, in which outgrowths originate from superior or inferior endplate margins of the vertebrae or discarthrosis (Castells Navarro & Buckberry 2020).

To increase the likelihood of a DISH diagnosis, the presence of *situs inversus* should also be confirmed. Many conditions are associated with *situs inversus*, for example, spinal anomalies such as congenital scoliosis, spina bifida, torticollis, Klippel-

Feil syndrome, and skull asymmetry (Chacón-Camacho et al. 2012; Johnson 1949; Mirasari et al. 2023). Most of these lesions can be observed in the spine, with scoliosis being among the most common. Despite its relative frequency, the co-occurrence of scoliosis and *situs inversus* is estimated at 1 in 200,000–1,250,000 individuals (Schlösser et al. 2017). Several studies (Burwell et al. 2006; Schlösser et al. 2017; Tallroth et al. 2009) indicate that the direction of the thoracic spinal curve in scoliosis may be influenced by visceral organ position. It is typically right-sided (75%) in individuals with normal organ placement and left-sided (79%) in individuals with *situs inversus* (Schlösser et al. 2017). Scoliosis was not observed in the spine of Individual 1. Individuals with Klippel-Feil syndrome typically have a short neck and limited head mobility due to defective segmentation of two or more cervical vertebrae. Although Chacón-Camacho et al. (2012) suggested a non-random association between Klippel-Feil syndrome and *situs inversus*, there are no data on the frequency of their co-occurrence. No cervical fusion or segmentation defects were observed in the analyzed individual. No spina bifida was observed in the vertebrae, nor were any lesions noted that could suggest torticollis.

Ankylosing spondylitis (AS) is another potential diagnosis that should be considered in the differential diagnosis of vertebral fusion. This condition typically involves the fusion of the sacroiliac joints and vertebral bodies, often beginning in the sacroiliac joint. Fusion of the costovertebral joints and ankylosis of the ribs to the spine are also common. The absence of "skipped" vertebrae—a pattern seen in this case—is consistent with the clinical presentation of AS (Waldron 2008). However, while AS primarily involves the lumbar vertebrae, it can extend to affect the thoracic spine as well (Holgate & Steyn 2016). In AS, vertebrae are fused through bony outgrowths at the margins, creating the appearance of a "bamboo spine" (Ortner 2003).

Both AS and DISH are more common in males, and the observed features—vertebral body fusion—could be indicative of either condition (Waldron 2008). However, according to Waldron (2008), a conclusive diagnosis of AS requires sacroiliac joint fusion in combination with continuous spinal ossification without skipped vertebrae.

Lesions observed within the vertebral column may also result from various other conditions, including degenerative joint diseases (DJD), which can lead to spinal fusion through the formation of marginal osteophytes. However, DJD does not necessarily occur in isolation and may co-occur with other spinal pathologies, such as DISH (Jankauskas 2003). In the case of Individual 1, varying degrees of marginal osteophyte formation were observed along the spine, primarily affecting C5 and C6, the thoracic vertebrae (T1–T6), lumbar vertebrae (L1–L5) (**Figure 5**), and the S1 vertebral body (**Figure 6**). Notably, the pattern of fusion between the T7–T11 vertebrae was inconsistent with the typical presentation of DJD, as it lacked the characteristic irregular, asymmetrical osteophyte formation and instead exhibited "dripping candle wax" pattern more indicative of DISH.

Figure 5. Lumbar vertebra (L5) with osteophytes (A and B) (photograph by Bilal Hammouri).

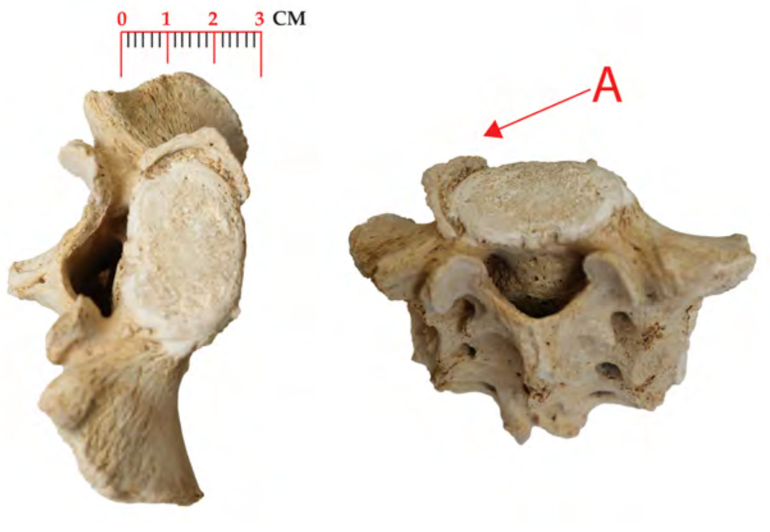

Figure 6. Sacral vertebra (S1) with osteophytes on the left lateral part of the S1 body (A) (photograph by Bilal Hammouri).

The possibility that the spinal lesions resulted from fluorosis was also considered, as this condition is more commonly observed in men over the age of 40. However, in such cases, fusion typically begins in the lumbar region, affecting the central part of the vertebral bodies and accompanied by narrowing of the intervertebral spaces (Foster et al. 2018; Waldron 2008). In the case of reactive arthropathy, lesions also occur more frequently in males, typically from the age of 15. The lesions are usually located in the lower thoracic and upper lumbar regions. Vertebral fusion involves the vertebral bodies and may exhibit a 'skip lesion' pattern, with unaffected vertebrae interspersed between affected ones. A similar presentation is seen in psoriatic arthropathy, which can also involve the vertebral bodies and display non-continuous fusion. Due to notable differences from the spinal lesions observed in Individual 1, these diagnoses are considered less likely (Foster et al. 2018; Waldron 2008).

Additional lesions observed on the spine included Schmorl's nodes (SN), which are characterized by the protrusion or herniation of intervertebral disc material into the adjacent vertebral bodies. These lesions were present in L1 and L4. According to Sadiq (2019), SNs are primarily considered a bone-related rather than a disc-related pathology. One of the key points of discussion surrounding SN is its rate of occurrence. While SNs are frequently observed in clinical studies, reported prevalence rates vary considerably. Moreover, Schmorl's nodes are commonly identified in osteological collections from across the globe, highlighting their widespread nature (e.g. Peeples 2018). In the case of Individual 1, some individual vertebrae demonstrated the presence of both osteophytes and SNs (**Figure** 7).

Joint disease

Degenerative joint disease (DJD) was observed in the distal femoral epiphysis and the proximal tibial epiphysis. Marginal osteophytes encircled the lateral condyle of

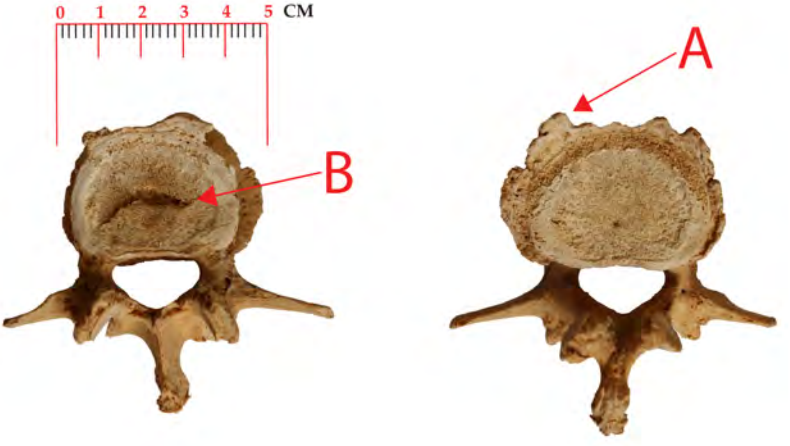

Figure 7. Lumbar vertebra (L4) with Schmorl's node on the upper surface of the body (A) and osteophytes on the lower rim of the body (B) (photograph by Bilal Hammouri).

the left femur, accompanied by pitting and eburnation (**Figure 8**)—classic indicators of articular cartilage degradation characteristic of osteoarthritis (OA), according to Waldron (2008). In contrast, the medial condyle showed only minor lesions, limited to the presence of marginal osteophytes. Similarly, more pronounced degenerative lesions were observed on the lateral condyle of the tibia (**Figure 9**). Additionally, bilateral linea aspera appear to display enthesopathies (**Figure 10**).

In addition, no osteophytes were noticed at the right knee joint and at bilateral tibia-fibula joints. Lesions in the knee joint most commonly occur in the patellofemoral joint, which is approximately twice as frequently affected as the tibiofemoral joint

Figure 8. The distal left femur with visible signs of joint pathology, including eburnation of the articular surfaces (A) and the presence of marginal osteophytes (B).

(Waldron 1995, 2008). They are more frequently observed in women than in men and are usually associated with obesity. OA most commonly affects individuals over the age of 40 (Waldron 2008).

Figure 9. Proximal tibia with signs of joint pathology, including presence of osteophytes on the margins (A) and eburnation of the articular surfaces (B).

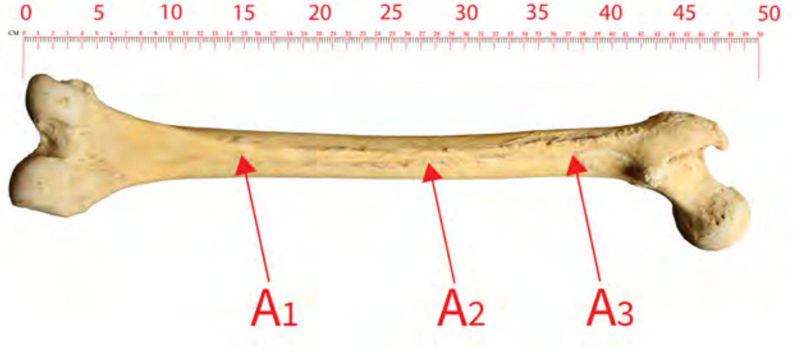

Figure 10. Enthesopathies on the linea aspera of left femur (photograph by Bilal Hammouri).

Discussion

The estimated age-at-death and sex of Individual 1 from Grave 1, together with the characteristic appearance of the spinal lesions, support the hypothesis that these lesions may be attributable to DISH. However, in the absence of other enthesopathic lesions, this diagnosis remains unconfirmed, particularly as the spinal ossification is located on the left side, whereas in a typical case of DISH, it tends to manifest on the right. Although left-sided ossification is possible (Waldron 2008), it would imply the presence of *situs inversus*, a rare condition, which typically has no impact on the individual's life. Interestingly, one such case has already been reported in excavation material (Charlier et al. 2012).

Although *situs inversus* may co-occur with other conditions, e.g. scoliosis, the frequency of such associations in most cases remains unknown. Therefore, the absence of these conditions cannot be regarded as evidence against the presence of *situs inversus*. In the present case, this interpretation is based solely on the spinal alterations, with no additional evidence to support such a diagnosis. This means that one unconfirmed diagnosis is being used to support another unconfirmed one, placing the entire interpretation under considerable uncertainty. Nevertheless, based on the visible spine lesions and despite the absence of definitive confirmation, DISH remains the most plausible diagnosis, even though no additional osteological features are present to confirm it conclusively.

DISH has been associated with several metabolic disorders, including obesity, type 2 diabetes (often linked to excess body weight), and gout, which can be influenced by diet (Brikman et al. 2024). Lifestyle-related factors are also believed to contribute to its development. Numerous cases have been documented in monastic cemeteries (Jankauskas 2003; Mays 2006; Waldron 2008), which has led to the suggestion of the possible link between DISH and specific dietary habits—particularly high-protein intake—observed among individuals of higher social status (Jankauskas 2003). However, $\delta^{13}C$ and $\delta^{15}N$ isotope analyses of human remains from the Romano-British site of Baldock (UK) and the Catalan Roman site of Santa Caterina (Spain) have not confirmed any consistent correlation between diet and the presence of DISH (Castells Navarro et al. 2022). Similarly, while obesity is frequently mentioned as a risk factor for DISH (Faccia et al. 2016), other research has not found strong evidence for this association (Paja et al. 2010), suggesting a multifactorial etiology (Castells Navarro & Buckberry 2020). In this individual, no osteological markers allow confirmation of obesity, and any link between body weight or diet and the development of DISH remains speculative.

Another condition noted in this individual was degenerative joint disease (DJD) of the knee, while other joints were completely normal. Although obesity (Gillespie & Porteous 2007; Lee & Kean 2012; Shumnalieva et al. 2023) is one of several potential risk factors for knee osteoarthritis, alongside advanced age, trauma, and abnormal mechanical loading (Waldron 2008), the unilateral nature of the lesion suggests trauma as the most likely cause. A multifactorial cause cannot be excluded, for instance, if the individual had been overweight, and trauma did ensue, this could have precipitated and also have aggravated the degenerative lesions. Nevertheless, given the absence of definitive osteological markers of obesity, any interpretation linking body weight to the observed pathology should be treated with caution. Regardless of its origin, the spinal lesions—specifically vertebral fusion not involving the costovertebral joints—were unlikely to have had a major impact on the individual's daily activities and may have been asymptomatic (Waldron 2008). Nevertheless, some degree of stiffness and reduced mobility might have been present (Jankauskas 2003). Additionally, the presence of Schmorl's nodes could have contributed to some degree of back discomfort (Kyere et al. 2012), while degenerative lesions in the knee joint may have been associated with chronic discomfort or limited mobility (Lagier 2006; Rogers et al. 2004), as well as discomfort linked to bone attrition, evidenced by visible eburnation.

In this context, the location of the individual's burial may provide further clues about his life. At the time, most of the population was buried extramurally (outside city walls), while intramural burials—those within church buildings—were typically reserved for the elite, clergy, and monastic communities (Samellas 2002). Burial within the church required considerable financial resources and was associated with prestige, especially due to the potential proximity to saints, martyrs, or relics. Clergy were commonly buried in the chancel, an area reserved for the most honored individuals within the church hierarchy. Members of the elite, by contrast, could be buried in other parts of the church, such as near the entrance or in the side aisles. Collective burials, as well as interments of children and infants, have also been recorded in these contexts (Clark 2024).

Grave 1 was located near the main entrance, which undermines the hypothesis that the individual was a member of the clergy. It appears more plausible that he belonged to the local elite. In this context, if the spinal lesions indeed represent DISH, their presence in this individual could reflect lifestyle and diet-related factors, as frequently reported cases among clergy and monastic populations are likely linked to such factors rather than religious role per se. The individual's elevated social status and the grave's intramural location may further support the plausibility of a DISH diagnosis. The unusual left-sided vertebral ossification may indicate an anatomical variation such as *situs inversus*, which is rarely reported in archaeological material (Charlier et al. 2012). Together with findings on degenerative joint disease, these results present a case that advances our understanding of chronic disease in Byzantine Jordan. DNA analysis could help clarify these diagnoses: previous studies have identified loci associated with DISH, including RUNX2, IL11, GDF5, CCDC91, NOG, and ROR2

(Sethi et al. 2023), while other analyses could detect genetic markers of *situs inversus* (Bartoloni et al. 2002; Eitler et al. 2022). Because the vertebral fusion in this individual occurs on the side opposite to what is typical for DISH, confirming either DISH or *situs inversus* would indirectly support the other. Similarly, isotopic studies ($\delta^{13}C$ and $\delta^{15}N$) could provide insights into the individual's diet, potentially confirming interpretations of and overall lifestyle. Such analyses had not been conducted at the time of writing this article.

If this were indeed a case of atypical presentation of DISH, it might suggest that the individual's diet was rich in protein or that he was obese, as higher social status could have been associated with greater access to protein-rich foods and an increased likelihood of obesity—both considered potential risk factors for DISH. The OA lesions observed in the knee could not be used to confirm the obesity hypothesis, as they were not symmetrical, suggesting they most likely resulted from trauma.

Conclusion

The osteological analysis of Individual 1 revealed several notable pathologies. The fusion of five consecutive thoracic vertebrae displaying a characteristic "dripping candle wax" appearance most plausibly indicates the presence of DISH, although this diagnosis cannot be confirmed with certainty. The atypical, left-sided distribution of vertebral fusion raises the possibility of *situs inversus*, yet this interpretation remains speculative in the absence of corroborating evidence. The co-occurrence of these conditions, if confirmed, would represent a highly unusual case.

Despite these uncertainties, the osteological and archaeological context provides valuable insight into the individual's life and social standing. The intramural burial suggests elevated status, possibly linked to dietary patterns associated with higher social classes—factors often discussed in relation to DISH. While there is no conclusive osteological evidence for obesity, certain skeletal features may indirectly suggest it. There is no conclusive osteological evidence for obesity, and the osteoarthritis observed in the left knee—most likely the result of trauma—may only hypothetically have been aggravated by age or body weight. All this uncertainty highlights the interpretative limitations inherent in palaeopathological diagnoses.

Future research, particularly ancient DNA analysis and isotopic studies, could help verify both the presence of DISH and the potential presence of *situs inversus*. Such approaches would not only clarify the medical condition of this individual but could also confirm the first identified case of *situs inversus* from this region.

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