# Diffuse idiopathic skeletal hyperostosis in an individual from the Late Roman cemetery at Histria

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**Abstract.** This study presents a palaeopathological analysis of an adult male individual (aged 43–55 years) interred in grave 27 of the Late Roman cemetery at Histria. The skeletal remains, though fragmentary, exhibit hallmark features of Diffuse Idiopathic Skeletal Hyperostosis (DISH) – a systemic, non-inflammatory condition characterised by ligamentous and entheseal ossification. The diagnosis is based on a macroscopic, pattern-based approach, emphasising the presence of flowing anterior ossification along the lumbar vertebrae L2–L5, sparing the intervertebral disc spaces. Complementary extraspinal enthesopathies were identified at the right patella and the distal ends of the first and third right metacarpals, marked by non-articular, hypertrophic bone proliferation at tendon and ligament attachment sites. Given the absence of imaging techniques and incomplete preservation of critical spinal regions, traditional exclusion-based differential diagnosis was not applicable. Instead, the study draws on clinical data to support a descriptive diagnosis, reinforcing the systemic nature and asymmetric distribution of DISH. The analysis also explores the biomechanical and functional consequences of the skeletal alterations. Lumbar ossification likely resulted in decreased spinal flexibility, compensatory stress at adjacent motion segments, and impaired postural dynamics. The enthesopathic changes in the metacarpals and patella would have diminished grip strength, thumb opposition, and knee extension efficiency, cumulatively affecting locomotion and manual tasks. This case highlights the diagnostic value of macroscopic analysis in bioarchaeology, especially when preservation is poor.
**Keywords:** palaeopathology; macroscopic analysis; diagnosis; enthesopathies; anterior spinal ossification.

**Hiperostoză scheletică idiopatică difuză la un individ din cimitirul roman târziu de la Histria.** Acest studiu prezintă o analiză paleopatologică a unui individ adult de sex masculin (vârsta la deces cuprinsă în intervalul 43–55 ani) înhumat în mormântul 27 din necropola romană târzie de la Histria. Deși se păstrează fragmentar, materialul osteologic analizat prezintă caracteristicile distinctive ale hiperostozei scheletice difuze idiopatice (DISH) – o afecțiune sistemică, neinflamatorie, caracterizată prin osificarea ligamentelor și entezelor. Diagnosticul se bazează pe evaluarea macroscopică a materialului scheletic, pornind de la tipare morfologice observate în alte

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cazuri ale acestei patologii, subliniind prezența osificării anterioare cu aspect de ceară care curge de-a lungul vertebrelor lombare L2–L5, fără a afecta spațiile intervertebrale ale discurilor. Au fost identificate enteziopatii extraspinale complementare la nivelul rotulei drepte și extremităților distale ale primului și celui de-al treilea metacarpian drept, marcate de proliferare osoasă hipertrofică non-articulară la nivelul regiunilor de fixare a tendoanelor și ligamentelor. Având în vedere absența tehnicilor de imagistică și conservarea incompletă a unor zone de interes pentru stabilirea patologiei, diagnosticul diferențial tradițional bazat pe excludere nu a fost aplicabil. În schimb, studiul se bazează pe informațiile clinice comparative pentru a susține un diagnostic descriptiv, consolidând natura sistemică și distribuția asimetrică a DISH. Analiza explorează, de asemenea, consecințele biomecanice și funcționale ale modificărilor apărute la nivelul scheletului ca urmare a acestui diagnostic. Osificarea lombară a dus probabil la scăderea flexibilității coloanei vertebrale, la solicitarea compensatorie la nivelul segmentelor de mișcare adiacente și la afectarea dinamicii posturale. Modificările enteziopatice ale metacarpienelor și rotulei au diminuat forța de prindere, opoziția degetului mare și eficiența extensiei genunchiului, afectând în mod cumulativ locomoția și sarcinile manuale. Cazul prezentat evidențiază valoarea de diagnostic a analizei macroscopice în bioarheologie, în special atunci când conservarea este precară.
**Cuvinte cheie:** paleopatologie; analiză macroscopică; diagnostic; enteziopatii; osificare anterioară a coloanei vertebrale.

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## I. Introduction

Diffuse Idiopathic Skeletal Hyperostosis (hereafter referred to as DISH), also known as Forestier disease, is a systemic, non-inflammatory condition characterised by the ossification of ligaments and entheses, particularly the anterior longitudinal ligament of the spine. While its pathogenesis remains multifactorial and not entirely understood, DISH is frequently associated with advanced age, metabolic disturbances, and reduced physical activity (Resnick, Niwayama 1976; Mader *et alii* 2009; 2013; Mader, Verlaan, Buskila 2013). DISH has garnered increasing attention in palaeopathological research not merely as an indicator of senescent skeletal change, but as a potential proxy for elevated social status, dietary excess, and broader patterns of metabolic health in past populations (Arriaza, Merbs, Rothschild 1993; Jankauskas 2003; Hlavenková *et alii* 2013; Quintelier *et alii* 2014).

The diagnostic framework for DISH in bioarchaeology typically follows the radiologically established criteria of Resnick and collaborators, adapted to the macroscopic examination of dry bone (Resnick, Shaul, Robins 1975; Resnick, Niwayama 1976; Resnick *et alii* 1978). These criteria emphasise the presence of flowing ossification along the anterior vertebral column, the preservation of intervertebral disc height, and the absence of apophyseal joint ankylosis or sacroiliac joint fusion. Extraspinal manifestations – particularly in the form of enthesophytes on the pelvis, knees, and hands – are increasingly recognised as important diagnostic and interpretive features (Van der Merwe, Maat, Watt 2012; Castells Navarro, Buckberry 2020).

This paper presents a case of DISH identified in an adult male individual interred in grave 27 at the Late Roman cemetery of Histria, the major Greek and Roman settlement located on the western coast of the Black Sea. The tomb, dated to the 4th–5th centuries AD, showed signs of partial disturbance and compression, yet the partially preserved skeleton reveals certain pathological alterations most notably flowing anterior vertebral fusion consistent with DISH, as well as extensive extraspinal enthesopathy affecting the right patella and first and third right metacarpals (Crețu, Dabîca, Soficaru 2024).

Due to the absence of radiological imaging and the incomplete preservation of key skeletal regions, including the sacroiliac joints, apophyseal joints, and posterior vertebral elements, a formal differential diagnosis – in the clinical sense – could not be fully pursued. Nevertheless, this limitation does not preclude meaningful and well-supported diagnostic interpretation in a palaeopathological context. Instead, this study employs a macroscopic, descriptive, and distribution-based approach, widely recognised in osteoarchaeological research as a valid and effective methodology for diagnosing systemic skeletal conditions like DISH. In archaeological samples, taphonomic processes frequently result in fragmentary preservation, precluding the application of imaging techniques or reliance on complete anatomical datasets. As such, anthropologists have developed morphology- and pattern-based diagnostic frameworks that emphasise the spatial distribution, anatomical specificity, and biomechanical coherence of observed lesions. Rather than relying on exclusion, this approach focuses on the positive identification of enthesopathic morphology, supported by comparative data. Such descriptive strategies are indispensable when conventional clinical tools are unavailable, allowing for nuanced reconstructions of disease expression, physical impairment, and lived experience in past populations.

## II. Materials and Methods

The skeletal remains analysed in this study belong to an adult male individual interred in grave 27, discovered in 2017 during systematic excavations in the South Sector of Histria, an area located outside the Late Roman fortification walls, specifically to the southwest of the urban enclosure, beyond the southern gate. The grave is a well-defined tile-built tomb, constructed with three rows of imbrices forming a gable-roofed structure. The edges of the pit were reinforced with greenschist fragments, and the foot end was sealed with a lid made of two stone slabs. The presence of six iron nails in the fill of the pit and along its entire length suggests the use of a coffin. The individual was placed in dorsal decubitus position, likely with hands resting on the pelvis, although dislocation and breakage due to compression have affected the region between the pelvis and skull. The orientation of the body was southwest

to northeast. Post-depositional pressures, particularly from the broken tile layers, further contributed to the fragmentation of skeletal elements in the thoracic and abdominal areas (**Pl. I**). No grave goods were found.

A detailed assessment of skeletal preservation was conducted, with results summarised in the anatomical chart presented in **Pl. II**. The remains are fragmentary but include diagnostically significant elements from both the axial and appendicular skeleton. Within the axial skeleton, notable preservation includes parts of the cranial vault, maxillae, and anterior bodies of the lumbar vertebrae L2–L5, which exhibit right-sided fusion. The thoracic cage and sternum are represented by rib fragments and a portion of the corpus sterni. The appendicular skeleton retains elements of the pectoral and pelvic girdles, upper and lower limbs, and portions of both hands and feet. Particularly relevant for diagnostic purposes are the right patella and the first to fourth right metacarpals. Despite the fragmentary condition, the preserved elements allow for meaningful palaeopathological analysis.

Macroscopic visual examination served as the primary diagnostic tool, focusing on the morphology, anatomical location, and surface texture of ossified regions. Particular emphasis was placed on enthesopathic changes – the ossification of soft tissue attachment sites – observed in both axial and appendicular elements.

The diagnostic criteria were adapted from Resnick and collaborators (Resnick, Shaul, Robins 1975; Resnick, Niwayama 1976; Resnick *et alii* 1978), originally formulated for radiological analysis but widely used in palaeopathological studies based on dry bone. The primary features considered were flowing ossification along the anterior vertebral column (in this case, L2–L5), and preserved intervertebral disc morphology. Although the third criterion, namely the absence of apophyseal joint ankylosis or sacroiliac joint fusion, is part of the classical framework, it could not be assessed in this case because those anatomical regions were not preserved.

In response to these limitations, the diagnostic approach adopted here follows a descriptive, pattern-based methodology, emphasising positive identification of a coherent suite of pathological changes, rather than differential exclusion. The co-occurrence of ligamentous spinal fusion and distinct extraspinal enthesophyte formation (in the patella and metacarpals) provides a strong basis for diagnosis, even in the absence of full axial preservation.

This diagnostic approach is further reinforced through comparative evidence from diverse regions and periods, where similar patterns of vertebral and extraspinal involvement have been observed in cases of DISH. In post-Mediaeval Western Europe, skeletal series from archaeological contexts frequently exhibit flowing anterior ossification of the thoracic and lumbar spine, in association with enthesopathic lesions of the patella, metacarpals, and feet – a pattern closely aligned with the remodelling seen in the individual from Histria (Rogers, Waldron 2001; Verlaan,

Oner, Maat 2007). In East Asia, particularly among individuals from Late Jomon Japan (1500–300 BC) and the Joseon Dynasty in Korea (16th–18th century AD), skeletal remains have shown consistent features of DISH, including lumbar ossification and extraspinal changes in the patella, hand, and foot bones, reinforcing the global distribution and diagnostic coherence of this condition (Oxenham, Matsumura, Nishimoto 2006; Kim *et alii* 2012). These regional and temporal parallels support the validity of a pattern-based diagnosis in archaeological settings.

The methodology is also grounded in a biomechanical-functional perspective, integrating osteological observations with principles from anatomical and functional studies. This includes evaluation of how ossification in key anatomical regions would have impacted joint mobility, tendon mechanics, and overall functional capacity. Such an approach enhances not only the diagnostic clarity, but also contributes to reconstructing the individual's physical experience and limitations in daily life.

## III. Sex and age-at-death estimation

The individual from grave 27 was determined to be a biological adult male, aged between 43 and 55 years at the time of death. Age estimation was based on the morphology and degree of metamorphosis of the sternal ends of the ribs, using standardised age-related criteria, which yielded a broad middle to late adult range (İşcan, Loth, Wright 1984a; 1984b). This was further refined by an analysis of cranial suture closure, which produced an age estimate of approximately 48.2 years, thus falling within and supporting the initially assessed range (Buikstra, Ubelaker 1994, p. 32–38).

Sex determination was performed by macroscopical evaluation through the scoring of available cranial traits, including the glabella, mastoid process, supraorbital margin, and external occipital protuberance. While mandibular features such as the mental eminence were not scorable due to fragmentation, the observed traits were consistent with a male sex designation, and the overall cranial morphology supported this conclusion. The assessment was conducted following established standards used in bioarchaeology (Buikstra, Ubelaker 1994, p. 32–38; White, Black, Folkens 2012, p. 410–411).

## IV. Pathological findings

The pathological alterations observed in the individual from grave 27/2017 are consistent with a systemic hyperostotic condition affecting both axial and appendicular components of the skeleton (**Pl. III**). Despite the overall incomplete and fragmentary state of preservation, several key regions – namely the anterior lumbar vertebrae (L2–L5), the right patella, and the first and third right metacarpals – are

preserved sufficiently to allow a confident macroscopic assessment of pathological changes. These findings are notable for their distribution, morphological features, and functional implications, all of which align with recognised patterns of DISH as documented in archaeological specimens (**Pl. III**).

The spinal pathology consists of a segmental fusion of at least four contiguous lumbar vertebrae via right-sided ossification along the anterior vertebral margins. This pattern follows the anatomical trajectory of the anterior longitudinal ligament, a hallmark feature of DISH. The lesion exhibits the characteristic "flowing candlewax" appearance and spares the intervertebral disc space, with no evidence of vertebral collapse, articular degeneration, or inflammatory erosions. This axial manifestation forms the diagnostic foundation for identifying DISH.

In the appendicular skeleton, significant enthesopathic changes are noted at multiple extraspinal sites. The right patella displays robust and asymmetrical ossification on its anterior surface, particularly at the quadriceps tendon insertion site, with evidence of long-term remodelling and surface porosity. Similarly, both the first and third right metacarpals exhibit non-articular, hypertrophic bony projections at the distal epiphyses – likely corresponding to tendon and capsular insertions of intrinsic and extrinsic hand muscles.

Together, these lesions reflect a systemically distributed pattern of ligamentous and entheseal ossification, consistent with the current understanding of DISH as a condition not limited to the spine but affecting a broad range of high-load anatomical insertion sites. The following subsections will present each pathological element in detail, addressing its morphological characteristics, anatomical context, biomechanical consequences, and relevance within the broader diagnostic picture.

### *IV. 1. The lumbar vertebrae*

The preserved vertebral segment includes the anterior portions of the lumbar vertebrae L2–L5, preserved as a continuous block fused along their right anterolateral margins. The anterior view (**Pl. IV/a**) displays the hallmark morphology of DISH: a flowing, asymmetrical hyperostosis resembling melted candle wax, descending uninterrupted across the anterior margins of at least three contiguous vertebrae. The ossification follows the anatomical trajectory of the anterior longitudinal ligament with large, bulbous protrusions especially prominent at the mid-to-lower margins of each vertebral body. These outgrowths merge seamlessly into the vertebral surfaces below, confirming the ligamentous, rather than marginal origin of the bone formation. The disc spaces remain visible, indicating preservation of intervertebral disc height – another diagnostic hallmark

of DISH that distinguishes it from spondylosis or intervertebral osteochondrosis (Resnick, Niwayama 1976, p. 559; Kuperus *et alii* 2017).

The posterior view (**Pl. IV/b**), showing the damaged internal spongiosa of the anterior body fragments, reveals a dense trabecular continuity between fused elements. While the dorsal elements are missing, the inner trabecular bridging supports the interpretation of chronic, enthesopathic ossification, not trauma-induced pseudoarthrosis or fracture callus. No features suggest inflammation, erosion, or marginal syndesmophyte formation. The absence of horizontal osteophytes or marginal lipping, typical in osteoarthritis, further strengthens the diagnosis of DISH over primary degenerative disc disease. The detail view of the anterior surface (**Pl. IV/c**) reveals both mature cortical ossification and vascular foramina, with a finely striated surface texture.

***IV. 2. The right first metacarpal***

The first metacarpal exhibits prominent pathological features concentrated at its distal epiphyseal region, primarily affecting the palmar and radial (lateral) aspects, but also extending medially. In the anterior view (**Pl. V/a**), the distal articular contour is obscured by an irregular, porous bony overgrowth that emerges from the palmar surface and projects slightly proximally. The remodelling appears hypertrophic, with asymmetric ossification affecting the zone where the palmar capsule, volar plate, and flexor tendon sheath insert.

The posterior view (**Pl. V/b**) shows a relatively preserved dorsal surface, with no notable lipping or bony proliferation across the dorsum of the head. This preservation supports a non-articular, enthesopathic process and rules out classic degenerative or inflammatory joint disease, which often targets the joint margin and articular surfaces.

The lateral view (**Pl. V/c**) is particularly revealing: the lesion demonstrates a curved, hook-like extension from the palmar head, protruding in a radial direction. This morphology is consistent with ossification at the insertion of the thenar muscles (particularly m. opponens pollicis) or the radial collateral ligament, both of which anchor deeply in this region. The lesion displays a coarsely textured surface and includes several vascular foramina or trabecular openings, suggestive of active remodelling over a prolonged period. The medial view (**Pl. V/d**) is less severely involved but shows continued thickening and irregularity of the metaphyseal surface, indicating some bilateral enthesopathic activity. The diaphyseal shaft remains well-formed with no periosteal reaction or curvature distortion, suggesting that the pathology is localised to the epiphyseal insertion zones and does not reflect diffuse skeletal dysplasia or trauma.

***IV. 3. The right third metacarpal***

The third metacarpal under examination displays pathological remodelling at its distal end, affecting primarily the anterior and medial aspects, but observable across all anatomical planes. In the anterior (palmar) view (**Pl. VI/a**) the distal metaphysis reveals a prominent, irregular osteophyte extending palmarward from the head of the bone, projecting beyond the expected margin of the articular surface. This growth appears lobulated and coarse, with a slightly shelf-like overhang, likely impinging upon or displacing the natural course of the flexor tendon sheath and palmar plate. From the posterior (dorsal) view (**Pl. VI/b**), the articular surface appears relatively intact, with no significant dorsal exostoses or collapse, confirming that the observed pathology is limited to extrasynovial or non-articular regions. This preservation is essential in excluding arthritic aetiologies such as osteoarthritis or rheumatoid arthritis, which typically compromise the articular cartilage and subchondral bone (Lories, Luyten 2011; Schett, Gravallese 2012; Suri, Walsh 2012).

In the lateral (**Pl. VI/c**) and medial (**Pl. VI/d**) views, the pathological outgrowth is shown to wrap asymmetrically around the palmar-medial margin of the metacarpal head. The lesion appears more voluminous medially, where a thickened, irregular bony protuberance disrupts the otherwise smooth metaphyseal contour. The osteophyte here likely represents ossification at the site of ligamentous insertion – particularly the medial collateral ligament of the metacarpophalangeal joint, or the anchor point for the fibrous flexor sheath. Surface texture is coarsely porous, with regions of vascular canal exposure, suggesting long-standing, active enthesopathic remodelling.

Collectively, these observations confirm the presence of a mature, non-inflammatory enthesophyte, originating at or near the insertion of stabilizing soft tissue structures on the distal metacarpal. The asymmetry and restriction to non-articular surfaces rule out common degenerative joint diseases, pointing instead toward systemic hyperostotic processes.

***IV. 4. The right patella***

The anterior surface of the right patella (**Pl. VII/a, c**) displays pronounced pathological remodelling marked by asymmetric bony hypertrophy, textural irregularity, and extensive enthesopathic activity. The superior and central zones of the anterior cortex reveal an elongated, striated depression flanked by irregular bony protrusions, clearly visible in the close-up (**Pl. VII/c**). The affected zone appears pitted and vascularised, with exposed canals and a granular cortical surface – hallmarks of chronic, remodelling bone formation. The bone's anterior contour is globular and uneven, and the normally smooth convex profile is disrupted by the

overgrowths. These features are highly consistent with enthesophyte formation due to sustained mechanical stress or systemic ossifying disease.

In contrast, the posterior surface of the patella (**Pl. VII/b**), which articulates with the femoral trochlea, appears smooth and well-preserved, with no evidence of cartilage erosion, pitting, eburnation, or articular collapse. This is a significant macroscopic indicator, as both osteoarthritis and rheumatoid arthritis typically involve destructive changes at the articular surface, especially in load-bearing joints like the patellofemoral compartment. In osteoarthritis, progressive loss of proteoglycans and collagen disorganisation leads to fibrillation, surface flaking, eburnation, and subchondral sclerosis, all of which become visible in advanced stages (Howell *et alii* 1976; Hughes 2009). Patellofemoral osteoarthritis often begins with lateral patellar cartilage degeneration due to malalignment or trochlear dysplasia. However, no such focal degeneration was observed. Furthermore, in rheumatoid arthritis, bone erosions preferentially emerge at bare areas where synovium directly contacts bone, typically presenting early as cortical breaches and progressing with pannus invasion, especially in peripheral joints. The preservation of the patellar articular surface, including the typically load-stressed lateral facet, thus provides strong macroscopic evidence against both inflammatory and degenerative arthropathies in this specimen (Schett, Gravallese 2012; Grelsamer, Dejour, Gould 2008).

## V. DISH diagnosis in the individual from Histria. A comparative approach

As already stated, the diagnosis of DISH in the individual from grave 27 at Histria is based on the identification of a coherent, systemically distributed pattern of non-inflammatory ossification, affecting both the axial and appendicular skeleton. Although the absence of certain key anatomical regions, particularly the sacroiliac joints, other complete elements from the vertebral column, and apophyseal joints, limits the application of traditional exclusion-based diagnostic frameworks, the preserved elements present a distinctive pathological signature consistent with DISH.

Central to this diagnosis is the flowing, right-sided ossification along the anterior margins of the L2–L5 vertebral bodies, which follows the anatomical trajectory of the anterior longitudinal ligament. The lesion exhibits the classic melted candlewax morphology, with no evidence of disc space collapse. An important diagnostic consideration in the present case is the right-sided distribution of vertebral ossification. This asymmetric pattern is well documented in both clinical literature and palaeopathological case studies. Comparative data from other archaeological contexts reinforce the diagnostic validity of such lateralisation.

At the cemetery of the Convent of the Soeurs Grises of Beauvais (Oise, France, 15$^{th}$–18$^{th}$ centuries), a probable case of DISH exhibited pronounced

anterior ossification along the right side of the thoracic spine, with flowing bony formations bridging vertebral bodies while sparing the intervertebral disc spaces. The ossification followed the trajectory of the anterior longitudinal ligament, and its asymmetry was noted as characteristic of the non-inflammatory ligamentous hyperostosis typical of DISH (Kacki, Villotte 2006).

In the clergy burials from the post-Mediaeval friary of Aalst, Belgium, one individual showed extensive anterior hyperostosis along the right thoracolumbar junction, again with preserved disc morphology and no evidence of inflammatory erosion or ankylosis. This was interpreted as part of a broader pattern of enthesopathic ossification involving both axial and extraspinal sites (Quintelier *et alii* 2014).

An individual from a collective burial at the 13th century Byzantine church of Taxiarches (Kastoria, Greece) also displayed spinal fusion predominantly along the right anterior vertebral margins, with matching enthesopathic changes in the lower limbs and feet. This supports the systemic and asymmetrical progression of DISH-related ossification in both spinal and extraspinal domains (Tritsaroli 2018).

The most geographically and chronologically proximate comparison comes from Late Roman Pécs (Sopianae), Hungary, where two adult male individuals exhibited right-sided ossification of the anterior thoracic spine, consistent with DISH. One individual, aged 60–70 years, displayed bridging of T8–T10 on the right side, with additional extraspinal enthesopathies at the pelvis and lower limbs. The second, aged 45–55 years, had extensive ossification from T4–T11, again predominantly right-sided, with preserved disc spaces and robust enthesophyte development in the ulna, femora, tibiae, and calcanei. Although minor apophyseal joint ankylosis was present in this second case, the authors argue this does not preclude a DISH diagnosis, due to the absence of erosive features and the overall coherence of systemic ossification (Hlavenková *et alii* 2013).

These parallels underscore the diagnostic significance of unilateral (particularly right-sided) anterior spinal ossification as a recognised variant of DISH. When combined with multiple extraspinal enthesopathies, the resulting pattern reflects the systemic and ligamentous ossification process characteristic of this condition.

Patellar involvement in DISH is underrecognised but has been increasingly documented. Enthesophyte formation on the anterior patella is linked to ossification at the insertion of the t. quadriceps femoris, a region subjected to considerable tensile forces. The biomechanics of this area – especially in individuals with decreased spinal mobility – suggest a compensatory loading mechanism that may exacerbate pathological mineralisation at the enthesis.

Drawing on skeletal material from Wells Cathedral in Somerset and the Royal Mint site in London, UK, anterior patellar enthesophytes were designated as among the most frequent extraspinal manifestations of DISH. The individuals

from these sites, primarily adult males interred between 12th–17th centuries AD, exhibited both vertebral hyperostosis and non-articular enthesopathic changes in the patellae and calcanei (Rogers, Waldron 2001).

A notable comparative case comes from the Joseon Dynasty Human Sample Collection in Korea, where four confirmed cases of DISH were documented, all in males over 50 years old. In Case 55 and Case 162, ossification of the quadriceps tendon insertion on the patella was clearly illustrated and described with macroscopic confirmation. In Case 55, a superior view of the right patella showed well-defined ossified outgrowth consistent with enthesopathic change, directly attributed to DISH-related systemic ossification. These cases also demonstrated right-sided spinal ossification, preserved disc spaces, and multiple extraspinal manifestations (Kim *et alii* 2012).

The first and third right metacarpals of the individual from Histria show marked non-articular bony proliferations at their distal (epiphyseal) ends. These lesions, projecting anteriorly and medially, are situated at anatomically consistent sites for tendon and joint capsule insertions. Their asymmetric, hypertrophic, and enthesophyte-like morphology – not centered on joint surfaces – points to a systemic enthesopathic process rather than age-related osteoarthritis or trauma. Given the anatomical specificity and systemic coherence of the observed hyperostoses, the metacarpal lesions in this case must be interpreted not in isolation but as integral to a broader pathological pattern, reinforcing the diagnosis of DISH.

Together, the right patella and the first and third metacarpals demonstrate a systemic pattern of non-articular enthesopathic ossification, anatomically consistent with the broader diagnostic framework of DISH. These lesions, in conjunction with the fused lumbar vertebrae, support the identification of a diffuse, ligamentous hyperostotic process rather than localised degenerative change. The cumulative effect of these changes on posture, gait, and manual dexterity is not to be underestimated. In order to better understand the lived implications of these skeletal alterations, attention must now be turned to their biomechanical and functional consequences.

## VI. Functional and biomechanical implications of DISH

Although the diagnosis of DISH rests primarily on the identification of systemic ossification patterns, its full significance cannot be understood without addressing the functional impact of the condition on the individual's biomechanics and daily life. In this context, the structural changes observed in the lumbar spine, right patella, and metacarpals must be examined not only as morphological alterations but as disruptors of mobility, mechanical efficiency, and musculoskeletal coordination.

This section considers the functional anatomy of the affected regions, drawing on clinical biomechanics and comparative anatomical studies (Pope 1989; Schreuders, Brandsma, Stam 2014; Wilke, Volkheimer 2018) to reconstruct the likely consequences of the lesions identified. Since the preserved elements pertain to key load-bearing and movement-generating structures – particularly the lumbar motion segments, thumb and hand joints, and the knee extensor mechanism – the pathological changes documented are interpreted in terms of their influence on postural control, locomotor function, and manual performance. To meaningfully assess the biomechanical implications of DISH in this case, an element-by-element approach has been adopted. Such an approach is highly relevant in palaeopathology, where skeletal lesions often provide the only available evidence for reconstructing impairment or limitation. When systemic ossification impairs the range of motion, alters tendon and ligament mechanics, or introduces compensatory strain patterns, these changes must be understood as part of the embodied experience of disease.

The lumbar spine, and especially the L2–L5 levels, serves as the primary region for sagittal-plane mobility in the human vertebral column. These segments account for 40–60% of total lumbar flexion-extension, significant portions of lateral bending and rotation, major transmission of axial compressive loads and shear forces. The anterior longitudinal ligament, which runs from the occiput to the sacrum along the anterior vertebral bodies, plays a crucial role in resisting spinal hyperextension and maintaining vertebral alignment. In DISH, this ligament undergoes progressive ossification, eventually forming a continuous bony bridge that severely limits segmental motion. The L2–L5 segment would normally allow an aggregate 30–40 degrees of flexion-extension. In this case, such motion is likely eliminated, resulting in a rigid spinal block. The mechanical burden is thus shifted to the adjacent segments: L1–L2 superiorly and L5–S1 inferiorly. These joints would have compensated for the loss of motion by becoming hypermobile, increasing their vulnerability to disc herniation, facet joint degeneration, and instability syndromes. The loss of intersegmental flexibility also alters force distribution through the spine. Normally, movement involves a balance between anterior vertebral motion and posterior facet guidance. With anterior fusion, the posterior elements may be subjected to abnormal shear and torsional stress, even if not directly involved in the pathology (Pope 1989; Ebraheim *et alii* 2004; Wilke, Volkheimer 2018).

In the individual from Histria, the loss of segmental mobility from L2–L5 would have resulted in noticeable functional stiffness, likely reducing the ability to perform activities involving deep flexion (e.g., squatting, lifting, twisting). Over time, this would have impacted locomotor function, postural control, and possibly contributed to muscle fatigue and chronic discomfort.

The first metacarpal is biomechanically and functionally unique among the metacarpals (Hirsch *et alii* 1974; Schreuders, Brandsma, Stam 2014). It articulates proximally with the trapezium at a saddle joint (carpometacarpal joint), permitting a wide range of motion including opposition, flexion, extension, abduction, and circumduction. Distally, it articulates with the proximal phalanx of the thumb at the metacarpophalangeal joint, which, although less mobile than other homologous joints, plays a key stabilising role in grip mechanics. Ossification in this area would have restricted the normal gliding of flexor tendons and reduced the elasticity of ligamentous and muscular insertions. The consequences would include loss of thumb flexion range, particularly in grasping motions, reduced opposition, impairing fine motor tasks like pinching, tool handling, or writing, and functional instability or discomfort, especially during repetitive hand tasks requiring forceful or precise digit placement.

The third metacarpal occupies a central anatomical and functional position in the human hand, anchoring the middle finger – the most structurally stable and mechanically loaded digit during both power and precision grips (Schreuders, Brandsma, Stam 2014). Its metacarpophalangeal joint plays an important role in force transmission during actions such as fist closure and three-jaw chuck positioning. The distal anterior surface of the third metacarpal serves as the attachment site for several key structures, as follows: the deep transverse metacarpal ligament, which stabilises the metacarpal heads transversely; the palmar plate, a fibrocartilaginous structure that resists hyperextension and supports flexor tendon guidance, and the fibrous flexor sheath, which encases the flexor digitorum superficialis and profundus tendons. Osteophyte formation in this region can compromise these functional units through multiple mechanisms. Bony overgrowth may cause mechanical impingement, restricting tendon gliding and leading to friction or triggering during finger flexion. Additionally, ossification at ligament insertion sites can contribute to joint stiffness by reducing ligament elasticity, thereby limiting metacarpophalangeal joint mobility (Minami *et alii* 1985). Even in the absence of overt inflammation, such structural alterations can result in pain or diminished fine motor control. Given the third digit's substantial contribution to grip strength, impairment of this joint likely had significant consequences for manual function, particularly in tasks involving repetitive or forceful hand use.

The combined morphological alterations of the first and third metacarpals strongly implicate biomechanical dysfunction. Both bones play a central role in grasping and manipulative hand movements. The third metacarpal anchors the central axis of the palm and contributes to force transmission during power grip, while the first metacarpal underpins thumb opposition and fine motor control. Degeneration at these points would restrict a wide range of thumb-finger

coordination, altering hand prehension patterns. Functionally, such alterations would likely result in significant limitations in both power grip (due to instability and pain in the third metacarpophalangeal joint) and precision grip (from trapeziometacarpal joint degeneration).

Anatomically, the metacarpophalangeal joints – especially of the second and third digits – are stabilised by interplays between the collateral ligaments, volar plates, flexor tendons, and the extensor hood. The observed bony projections along the distal articular margins of the third metacarpal likely compromise the collateral ligament insertions. A recent study emphasises the tension-dependent behaviour of collateral ligaments in different phases of metacarpophalangeal motion. Increased rigidity of these structures, particularly during flexion, would be exacerbated by osteophytic encroachment, mechanically locking the joint or predisposing it to capsular strain and ligament attenuation (Boccolari *et alii* 2024).

Anatomically, the patella is a sesamoid bone embedded within the quadriceps tendon. It functions to increase the leverage of the quadriceps muscle during knee extension by increasing the angle of insertion, to protect the anterior knee joint, and to guide the quadriceps tendon and patellar ligament across the distal femur. The anterior surface of the patella serves as the insertion point for the quadriceps tendon superiorly and is enveloped by connective tissue that stabilises and transmits force from the thigh to the tibia. In the case presented here, ossification of the superior and central anterior surface would have likely involved the deep fibres of the quadriceps enthesis and potentially part of the retinacular expansions.

This pathological ossification would have mechanically stiffened the quadriceps attachment reducing its elasticity and potentially impairing the transmission of force during active knee extension. Such a modification would alter the mechanics of the extensor apparatus, increasing stress on the patellar tendon, tibial tuberosity, and adjacent soft tissues. The observed anterior hypertrophy would likely have affected the function of this system by altering tendon tension and movement, possibly impeding the sliding mechanism of the quadriceps tendon over the patella, restricting flexion-extension range due to mechanical impingement or tethering at the level of the extensor mechanism, causing anterior knee pain, particularly during loaded flexion activities such as kneeling, squatting, or climbing (Kaufer 1979; Heegaard *et alii* 1995).

Taken together, the structural changes observed in the lumbar spine, patella, and metacarpals illustrate the biomechanical implications of DISH, viewed as a condition with real, tangible effects on the physical body. The fusion of the L2–L5 vertebrae would have created a rigid spinal segment, significantly reducing flexibility, particularly in movements requiring trunk flexion or rotation, and likely leading to compensatory hypermobility and strain at adjacent levels. When coupled

with enthesopathic changes in the right patella – critical to force transmission during knee extension – and the ossification along key regions of the metacarpals that underpin thumb and finger mechanics, a cumulative picture of constrained, effortful movement emerges. The chronic and progressive nature of the ossification would have resulted in the gradual loss of biomechanical efficiency, leading to pain, fatigue, and diminishing adaptability of the musculoskeletal system. Manual tasks requiring precision or grip strength, locomotor actions involving dynamic knee flexion, and basic postural adjustments relying on lumbar mobility would all have been altered or impaired.

## VII. Conclusions

Given the fragmentary preservation of the skeleton and the absence of imaging tools, the identification of DISH in the individual buried in grave 27 from the Late Roman cemetery at Histria was based on a descriptive and distribution-based macroscopic diagnostic approach, emphasising positive identification of lesions over differential exclusion. The study diagnosed DISH based on hallmark vertebral fusion (L2–L5) and extraspinal enthesopathy in the right patella and first and third metacarpals. The observed flowing anterior ossification – right-sided and sparing the disc spaces – alongside localised, non-articular bone proliferation at tendon insertions, form a coherent pathological profile characteristic of DISH.

The case presented in this paper also fits within the broader comparative framework that links DISH with age, male sex, and potential metabolic predispositions. DISH is increasingly recognised in palaeopathological literature as a condition associated with advanced age, male sex, and certain lifestyle patterns, particularly those related to metabolic health and physical activity levels. Studies confirm age as the most consistent determinant of DISH prevalence. The disorder primarily affects middle-aged and older adults, with almost no cases reported in younger individuals. Sex is another consistent factor; across nearly all archaeological populations examined, DISH is more frequently diagnosed in males (Arriaza 1993; Arriaza, Merbs, Rothschild 1993; Jankauskas 2003; Verlaan, Oner, Maat 2007).

In modern clinical literature, DISH is also strongly associated with metabolic syndrome, including obesity, insulin resistance, and type 2 diabetes mellitus. Recent studies have demonstrated significantly higher rates of DISH in individuals with elevated body mass index, metabolic disturbances, or a family history of diabetes and hypertension (Kiss *et alii* 2002; Mader, Lavie 2009; Sarzi-Puttini, Atzeni 2004). Furthermore, recent data confirm a high prevalence of DISH in young obese patients (under age 50), suggesting that obesity itself may act as an independent and early risk factor for the condition (Brikman *et alii* 2024). Although such comorbidities cannot be directly assessed in archaeological cases — as soft tissue, adiposity, and

metabolic markers do not preserve in the osteological record — their growing recognition in clinical settings supports the view of DISH as a systemic disorder influenced by long-term metabolic imbalance. This interpretive gap underscores a fundamental limitation of palaeopathological diagnosis: the inability to confirm conditions like obesity, insulin resistance, or type 2 diabetes without biochemical or histological evidence. In this sense, the bioarchaeological analysis of DISH relies on inference rather than confirmation, extrapolating from skeletal manifestations that may reflect, but do not prove, underlying metabolic syndromes.

While numerous palaeopathological studies have linked DISH to elevated social status, often in contexts involving monastic or elite burials marked by dietary excess or reduced physical labor (Rogers, Waldron 2001; Jankauskas 2003; Kacki, Villotte 2006; Quintelier *et alii* 2014), the case from Histria requires a more nuanced interpretation. Based on the archaeological data retrieved from the South Sector at Histria, it is not currently possible to draw socially or hierarchically relevant inferences regarding the placement of grave 27 within the cemetery layout. The grave shares construction features common to many other contemporaneous interments – namely, a gabled tile roof and greenschist reinforcement – thus it does not stand out architecturally or materially in ways that might imply elevated social or ritual status. The absence of grave goods, coupled with the overlapping of this burial by grave 28, further suggests that the grave may not have held significant spatial or symbolic prominence within the mortuary landscape. Therefore, any speculation about the individual's social rank based on spatial positioning alone would be methodologically unsound in this context. With the notable exception of grave 58, a richly furnished female burial positioned along the longitudinal axis of the basilica[2], the cemetery appears to lack overt markers of social stratification – either through differential burial types or selective artefact distribution. In the absence of stable isotope data, dietary reconstructions, or contextual clues of social differentiation, a cautious interpretative stance must be adopted. Rather than interpreting the grave's location or characteristics as indicative of social rank, the

[2] Grave 58 was located just east of the apse of the Basilica Extra Muros at Histria, aligned with the church's longitudinal axis and only about 1.2 m from its eastern end. This position placed the burial in a central spot within the church courtyard, suggesting deliberate placement to emphasise the individual's importance. Its location near the basilica – notably close to what may have been a small annex or chapel – indicates a privileged burial context, possibly linked to early Christian practices of burying notable individuals near sacred spaces. The grave was a stone-lined cist measuring approximately 2 m in length, built with stone blocks bonded with clay, and lined at the base with square bricks. It was covered by a lid made of horizontally arranged bricks, and evidence of iron nails and wood remains suggest the use of a wooden coffin. The burial included a set of gold artefacts consisting of two oval buckles with fitting plates depicting stylised animal heads – two strap ends crafted by hammering gold sheets, and two rectangular gold fittings engraved with crosses. Additionally, fragments of gold thread were found near the neck and wrists, indicating an embroidered garment (Hamparţumian 1971; Creţu, Soficaru 2022).

burial should be understood as part of a relatively uniform extramural funerary landscape that served the broader community during the Late Roman period.

This case demonstrates the value of integrating detailed morphological analysis with comparative contextual data to achieve diagnostic clarity in the absence of complete anatomical evidence. It exemplifies an approach for bioarchaeological diagnosis that remains methodologically rigorous while also sensitive to the realities of preservation.

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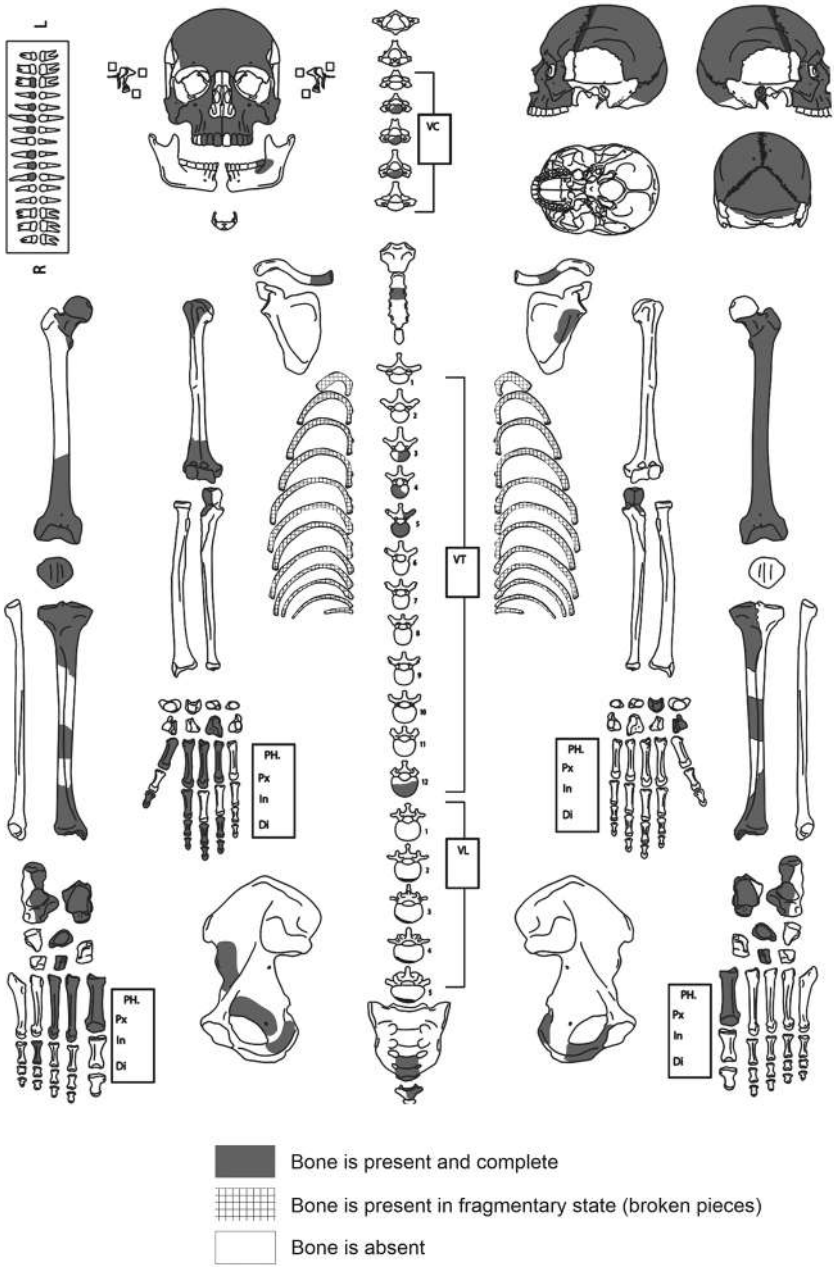
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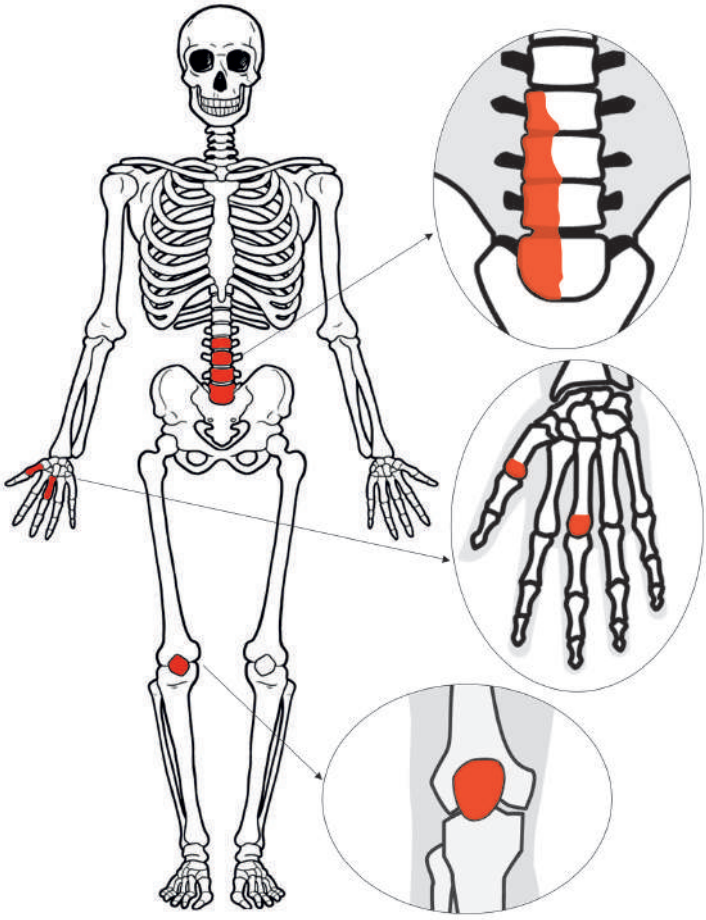
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**Pl. I.** Grave 27. Photos: M. Dabîca ("Vasile Pârvan" Institute of Archaeology).
**Pl. I.** Mormântul 27. Foto: M. Dabîca (Institutul de Arheologie „Vasile Pârvan").




**Pl. II.** Visual inventory form for the skeleton found in grave 27 (after Bocquentin, Anton 2021).
**Pl. II.** Fișă de inventar pentru scheletul descoperit în mormântul 27 (după Bocquentin, Anton 2021).



**Pl. III.** Skeletal diagram showing the bones affected by DISH.
**Pl. III.** Diagramă cu oasele scheletului afectate de DISH.



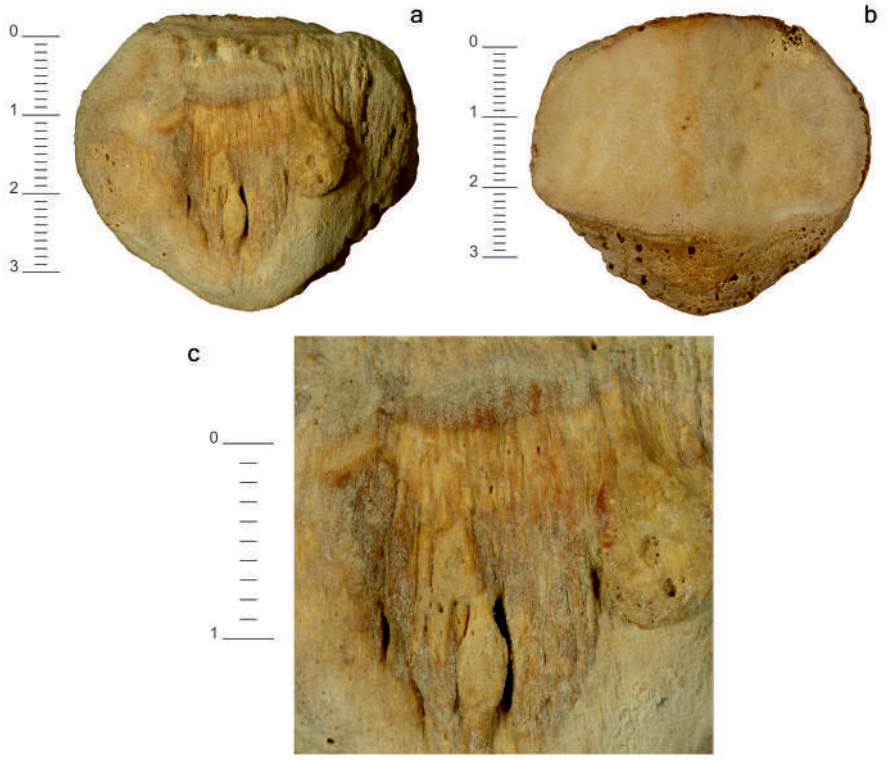

**Pl. IV.** Segment of the lumbar spine (L2–L5).
a. anterior view; b. posterior view; c. anterior view (detail).
**Pl. IV.** Segment al coloanei lombare (L2–L5).
a. vedere anterioară; b. vedere posterioară; c. vedere anterioară (detaliu).




**Pl. V.** The right first metacarpal. a. anterior (palmar) view;
b. posterior (dorsal) view; c. lateral view; d. medial view.
**Pl. V.** Metacarpianul I de pe partea dreaptă. a. vedere anterioară (palmară);
b. vedere posterioară (dorsală); c. vedere laterală; d. vedere medială.




**Pl. VI.** The right third metacarpal. a. anterior (palmar) view;
b. posterior (dorsal) view; c. lateral view; d. medial view.
**Pl. VI.** Metacarpianul III de pe partea dreaptă. a. vedere anterioară (palmară);
b. vedere posterioară (dorsală); c. vedere laterală; d. vedere medială.




**Pl. VII.** The right patella. a. anterior view; b. posterior view;
c. anterior view (detail).
**Pl. VII.** Rotula dreaptă. a. vedere anterioară; b. vedere posterioară;
c. vedere anterioară (detaliu).