

GENERAL NOTIONS ON THE IDENTIFICATION OF ELEMENTS ASSOCIATED WITH TUBERCULOSIS IN FORENSIC ANTHROPOLOGY: A PRELIMINARY LITERATURE REVIEW

**NOÇÕES GERAIS DE IDENTIFICAÇÃO DE ELEMENTOS ASSOCIADOS À
TUBERCULOSE NO CAMPO DA ANTROPOLOGIA FORENSE: UMA REVISÃO
BIBLIOGRÁFICA PRELIMINAR**

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ABSTRACT

This article presents a preliminary literature review on the identification of pathological lesions associated with tuberculosis (TB) within the scope of forensic anthropology. The evaluation of infectious skeletal alterations has gained prominence as an auxiliary tool in individualization and biological profiling, particularly when antemortem medical records or imaging examinations are available. Classic osteoarticular manifestations, such as tuberculous spondylitis (Pott's disease), and minor osseous lesions attributable to tuberculosis (MOLAT)—including visceral rib periostitis, vertebral hypervascularization, and endocranial changes—validated through identified skeletal collections (such as Coimbra and Bologna), are analyzed. The relevance of differential diagnosis against other granulomatous or neoplastic conditions is discussed, as well as the application of advanced radiological techniques (3D computed tomography) for confrontational comparison between antemortem and postmortem data. It is concluded that meticulous analysis of these morphological alterations enhances diagnostic sensitivity in human remains, reinforcing the evidentiary value of bone pathology in positive forensic identification.

Keywords: Forensic anthropology; Osteoarticular tuberculosis; Pott's disease; Minor osseous lesions (MOLAT); Human identification.

RESUMO

Este artigo apresenta uma revisão bibliográfica preliminar sobre a identificação de lesões patológicas associadas à tuberculose (TB) no contexto da antropologia forense. A avaliação de alterações esqueléticas infecciosas tem ganhado destaque como recurso auxiliar no processo de individualização e reconstrução do perfil biológico, sobretudo quando há disponibilidade de registros médicos ou exames de imagem antemortem. Analisam-se as

manifestações osteoarticulares clássicas, como a espondilite tuberculosa (doença de Pott), e as lesões menores atribuíveis à tuberculose (MOLAT), incluindo periostite visceral costal, hipervascularização vertebral e alterações endocranianas, validadas a partir do estudo de coleções osteológicas identificadas (como Coimbra e Bolonha). Discute-se a relevância do diagnóstico diferencial frente a outras afecções granulomatosas ou neoplásicas, bem como o emprego de técnicas radiológicas avançadas (microtomografia computadorizada 3D) para a comparação confrontativa entre dados antemortem e postmortem. Conclui-se que a análise minuciosa dessas alterações morfológicas amplia a sensibilidade e a precisão do diagnóstico patológico em remanescentes ósseos humanos, reforçando o valor probatório das lesões ósseas na identificação forense positiva.

Palavras-chave: Antropologia forense; Tuberculose osteoarticular; Doença de Pott; Lesões ósseas menores (MOLAT); Identificação humana.

INTRODUCTION

Forensic anthropology is a discipline concerned with the analysis of human skeletal remains, whether skeletonized or partially skeletonized, for the purposes of individual identification and reconstruction of the circumstances surrounding death. It has increasingly incorporated the assessment of pathological changes as potentially individualizing features. Although classical methods for estimating the biological profile—including sex, age, ancestry, and stature—and the comparison of unique anatomical characteristics, such as frontal sinuses and dental features, remain central to forensic identification, recent literature has highlighted the value of pathological bone lesions when antemortem records

are available (MARTRILLE *et al.*, 2020). In the context of tuberculosis (TB), a chronic infectious disease caused by microorganisms belonging to the *Mycobacterium tuberculosis* complex, skeletal manifestations, although occurring in only 1–5% of untreated clinical cases, may exhibit sufficiently distinctive morphological patterns to contribute to positive identification, as demonstrated in contemporary forensic cases (MARTRILLE *et al.*, 2020; ORTNER, 2003). The integration of these findings expands the possibilities for individualization in contexts where other anatomical characteristics are compromised or unavailable.

The literature demonstrates that tuberculosis represents an important subject of investigation in the study of human remains, particularly because certain osteopathological manifestations may remain preserved in the skeleton after death. Reported findings include vertebral lytic lesions, vertebral body collapse, and kyphosis associated with Pott disease, as well as extravertebral osteolytic lesions, joint ankylosis, and new bone formation on the internal surfaces of the ribs. However, such alterations should not be interpreted in isolation as pathognomonic of tuberculosis, and caution is therefore required in anthropological and medicolegal assessments. Contemporary paleopathology has expanded this approach through the integration of macroscopic analysis, imaging methods, and biomolecular techniques, including the analysis of ancient DNA (aDNA). These advances have not only enhanced our understanding of the historical presence of tuberculosis but have also provided deeper insights into the evolution of the *Mycobacterium tuberculosis* complex and its long-standing interactions with human populations (BUZIC; GIUFFRÀ, 2020).

Within this context, the interface between tuberculosis, forensic anthropology, and paleopathology extends beyond merely historical interest, as it enables a more comprehensive understanding of disease-related evidence preserved in human remains and of the interpretive limitations associated with its analysis. Although the identification of changes compatible with tuberculosis may contribute to the biological and pathological characterization of skeletonized individuals, retrospective diagnosis remains methodologically challenging and requires the integration of multiple lines of evidence. The evolution of diagnostic techniques applied to the paleopathological investigation of tuberculosis demonstrates the increasing importance of combining osteological assessment with laboratory and molecular methods, while also highlighting gaps and limitations that must be considered when interpreting the findings (PAPA *et al.*, 2023). Accordingly, this study aims to critically discuss tuberculosis within the field of forensic anthropology, with emphasis on its osteopathological manifestations, diagnostic strategies applicable to human remains, and the contributions and limitations of biomolecular approaches. In doing so, it seeks to systematize the principal foundations underlying the investigation of tuberculosis in forensic anthropological contexts and to emphasize the need for a multidisciplinary, technically grounded, and methodologically cautious approach.

METHODS

This study consisted of a preliminary bibliographic review of the scientific literature with a theoretical and descriptive approach. The search and selection of bibliographic sources included reference textbooks in paleopathology and forensic anthropology, doctoral

dissertations, and scientific articles indexed in international databases. Priority was given to studies addressing the epidemiology and skeletal manifestations of the *Mycobacterium tuberculosis* complex, paleopathological diagnostic criteria—including classic Pott disease lesions and minor lesions (MOLAT)—analyses of identified skeletal collections, such as those from Coimbra and Bologna, and forensic case reports involving the superimposition of antemortem and postmortem tomographic images. The extracted data were qualitatively analyzed and critically structured to provide a diagnostic and forensic synthesis.

Reference selection was guided by thematic pertinence, quality, and scientific relevance to the objectives of the study, with priority given to publications presenting data on skeletal manifestations, diagnostic methods, biomolecular evidence, and medicolegal applications of tuberculosis investigation in human remains. Studies that did not provide a direct contribution to the scope of the review and lacked specific relevance to human remains, paleopathology, forensic anthropology, or the retrospective diagnosis of tuberculosis were excluded.

RESULTS AND DISCUSSION

Osteoarticular tuberculosis accounts for approximately 1–3% of all tuberculous infections and preferentially affects the spine, which is involved in approximately 50% of skeletal cases, followed by weight-bearing joints such as the hip and knee (SANTOS; SUBY, 2012). Hematogenous dissemination from a primary pulmonary focus or, less frequently, direct extension by contiguity results predominantly in lytic lesions, with limited reactive bone formation during the early stages of the disease (ORTNER, 2003). In the skeleton, the classic and

most diagnostically relevant manifestation is tuberculous spondylitis, or Pott disease, characterized by destruction of the anterior vertebral bodies, vertebral collapse, angular kyphosis (gibbus deformity), and, frequently, relative preservation of the neural arch and intervertebral disc space during the early stages (SANTOS; SUBY, 2012; ROBERTS; BUIKSTRA, 2003). Studies of identified skeletal collections and paleopathological material have confirmed that the thoracolumbar region is the most frequently affected and that the presence of multiple lesions or “skip lesions” strengthens the diagnostic suspicion (HOLLOWAY *et al.*, 2011).

In addition to the classic destructive lesions, paleopathological and forensic literature has increasingly emphasized the so-called “minor osseous lesions attributable to tuberculosis” (MOLAT), a concept systematized by Maczel (2003). These include periosteal new bone formation on the visceral surface of the ribs, vertebral hypervascularization, characterized by enlarged foramina and circular erosions of the vertebral bodies, endocranial alterations suggestive of tuberculous meningitis, and diffuse hypertrophic osteoarthropathy (MACZEL, 2003; KELLEY; MICOZZI, 1984). Studies of documented skeletal collections, such as the Coimbra Identified Skeletal Collection and the Certosa cemetery collection in Bologna, have demonstrated a statistically significant association between these alterations and tuberculosis-related causes of death, including both pulmonary and extrapulmonary TB (SANTOS, 2000; MARIOTTI *et al.*, 2015). Rib new bone formation, in particular, exhibited a prevalence exceeding 50% among individuals who died from TB, although this finding is not pathognomonic, as it may also occur in other chronic pulmonary diseases (SANTOS; ROBERTS, 2001; MARIOTTI *et al.*, 2015).

The analysis of identified skeletal collections from the late nineteenth and early twentieth centuries, corresponding to the pre-antibiotic era, has been fundamental for validating diagnostic criteria. In Coimbra, Santos (2000) correlated macroscopic, radiological, and biomolecular lesions with death records, demonstrating the diagnostic utility of combining classic and minor indicators. In Bologna, Mariotti *et al.* (2015) observed that larger foramina and internal cavities detected by computed tomography in vertebrae without evident external lesions were significantly more frequent among individuals whose cause of death was tuberculosis. These findings may increase diagnostic sensitivity in forensic contexts, where skeletal preservation may be incomplete and classic Pott disease lesions may be absent (SANTOS; SUBY, 2012; MARIOTTI *et al.*, 2015). The reanalysis of skeletons examined decades ago in light of these newly established criteria has been recommended as a strategy for improving our understanding of the prevalence and skeletal expression of the disease (SANTOS; SUBY, 2012).

In the strictly forensic context, the utility of tuberculous lesions for individual identification was paradigmatically demonstrated by Martrille *et al.* (2020). In a case involving skeletal remains with typical Pott disease lesions and other osseous alterations, the superimposition of antemortem and postmortem computed tomography images, including three-dimensional reconstructions, allowed the establishment of correspondences in lesion position, anatomical contour, character (lytic and/or blastic), and detailed morphology (MARTRILLE *et al.*, 2020). The authors argued that, although many individuals may exhibit tuberculous lesions, the specific morphological characteristics of lesions in an individual case may have evidentiary value comparable to that of primary identifiers when assessed against previously available clinical documentation

(MARTRILLE *et al.*, 2020; ORTNER, 2003). This approach reinforces the need for the systematic incorporation of skeletal pathology assessment into forensic identification protocols.

Differential diagnosis remains a major challenge. Destructive vertebral lesions may mimic pyogenic spondylodiscitis, metastatic neoplasms, or other granulomatous infections, such as brucellosis (SANTOS; SUBY, 2012; ORTNER, 2003). Relative preservation of the intervertebral disc, the presence of calcifications, anterior vertebral involvement, and “cold” paravertebral abscesses are findings that favor TB (ROBERTS; BUIKSTRA, 2003). In the ribs, periosteal new bone formation must be differentiated from reactions associated with trauma, neoplasms, or other infectious processes (KELLEY; MICOZZI, 1984; SANTOS; ROBERTS, 2001). The literature recommends integrating macroscopic and radiological data—including conventional radiography, computed tomography (CT), micro-computed tomography (micro-CT), and, when available, magnetic resonance imaging (MRI)—with biomolecular approaches in research settings, although the latter are rarely available in routine forensic practice (SANTOS, 2000; HOLLOWAY *et al.*, 2011).

The relatively low frequency of skeletal involvement in clinical TB indicates that the absence of skeletal lesions does not exclude the disease, whereas the presence of compatible patterns increases diagnostic probability, particularly when multiple indicators coexist (HOLLOWAY *et al.*, 2011; SANTOS; SUBY, 2012). In contemporary forensic contexts, the increasing availability of digital medical records and antemortem imaging examinations further expands the potential use of these alterations as individualizing features (MARTRILLE *et al.*, 2020). Accordingly, the reassessment of historical skeletal collections and the careful application of validated criteria to

documented series represent essential strategies for improving forensic anthropology practice in the identification of individuals with a history of osteoarticular tuberculosis (MACZEL, 2003; MARIOTTI *et al.*, 2015).

Table 1 and the infographic (Figure 1) below summarize, based on the discussion presented in this article, the main morphological indicators (classic and minor) associated with tuberculosis in osteological material, together with their descriptions, diagnostic and forensic value, and the principal references supporting their validation or application.

Table 1. Main osteological features associated with tuberculosis and key reference studies discussed in this article.

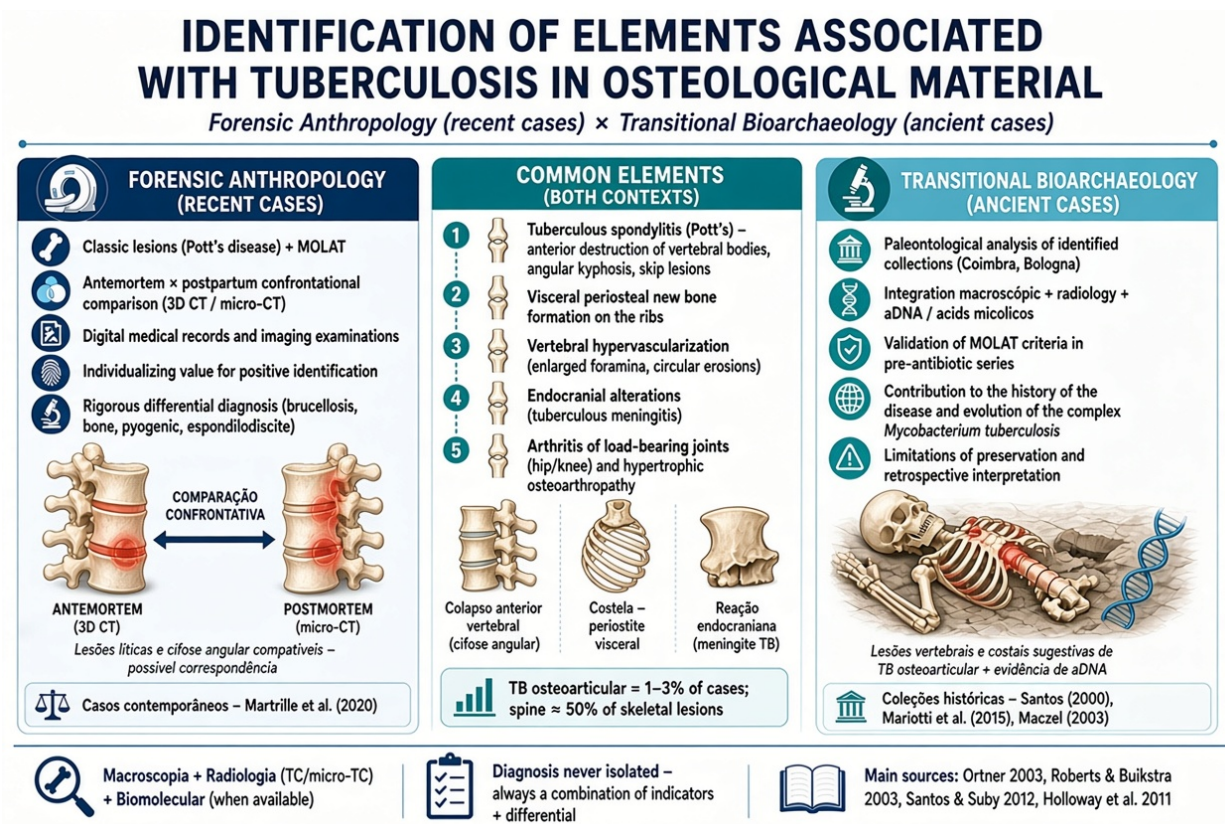
Lesion / Feature Type	Morphological Description and Location	Diagnostic and Forensic Value	Key Studies Discussed
Tuberculosis spondylitis (Pott disease) – classic lesion	Predominantly lytic destruction of the anterior vertebral bodies; vertebral collapse; angular kyphosis (gibbus deformity); relative preservation of the neural arch and intervertebral disc space during the early stages; preferential involvement of the thoracolumbar region; possible presence of <i>skip lesions</i> and “cold”	The most characteristic and diagnostically relevant lesion of skeletal TB, occurring in approximately 50% of osteoarticular cases. Diagnostic suspicion is substantially increased when associated with other indicators. In forensic contexts, it allows detailed comparison with antemortem imaging, including	Ortner (2003); Roberts & Buikstra (2003); Santos & Suby (2012); Holloway <i>et al.</i> (2011); Martrille <i>et al.</i> (2020) – forensic case involving 3D CT superimposition of antemortem and postmortem images.

	paravertebral abscesses.	lesion contour, lytic/blastic character, and morphology.	
Periosteal new bone formation on the visceral surface of the ribs (MOLAT)	Periosteal reaction and new bone formation on the visceral (internal) surface of the ribs.	A minor indicator with high prevalence (>50% among individuals with TB-related causes of death in identified skeletal collections). It is not pathognomonic, as it may occur in other chronic pulmonary diseases, but it may increase diagnostic sensitivity, particularly when combined with other MOLAT indicators.	Kelley & Micozzi (1984); Santos (2000); Santos & Roberts (2001); Mariotti <i>et al.</i> (2015); Maczel (2003).
Vertebral hypervascularization (MOLAT)	Enlarged vascular foramina, circular erosions, and internal cavities within the vertebral bodies, including cases without evident external lesions. These alterations may be detected by computed tomography.	Statistically associated with TB-related causes of death in documented skeletal collections. It may improve diagnostic sensitivity in partially preserved skeletons or in cases lacking classic Pott disease lesions.	Mariotti <i>et al.</i> (2015) – Certosa collection (Bologna); Santos (2000) – Coimbra Identified Skeletal Collection; Maczel (2003).
Endocranial alterations	Lesions suggestive of tuberculous	A minor indicator of meningeal	Maczel (2003); Santos (2000);

(MOLAT)	meningitis, including alterations affecting the internal surface of the cranial vault.	involvement that may strengthen the overall body of evidence when present.	studies of identified skeletal collections from Coimbra and Bologna.
Diffuse hypertrophic osteoarthropathy and tuberculous arthritis (MOLAT / classic)	Involvement of weight-bearing joints, particularly the hip and knee; ankylosis; and new bone formation.	Complements the assessment of osteoarticular TB, which accounts for approximately 1–3% of all tuberculous infections. It may be useful for differential diagnosis and individualization when supported by antemortem clinical documentation.	Ortner (2003); Santos & Suby (2012); Maczel (2003).
Combination of multiple indicators (classic lesions + MOLAT)	Co-occurrence of vertebral lytic lesions, visceral rib periostitis, vertebral hypervascularization, and/or endocranial alterations.	Increases the overall diagnostic probability. In forensic anthropology, case-specific morphological characteristics may have evidentiary value comparable to primary identifiers when assessed against antemortem medical records and imaging studies.	Martrille <i>et al.</i> (2020); Santos (2000); Mariotti <i>et al.</i> (2015); Santos & Suby (2012); Holloway <i>et al.</i> (2011).

Source: Prepared by the authors (2026).

Figure 1. Infographic developed based on the elements discussed in the present study, including classic lesions, MOLAT, diagnostic methods, and differences between recent forensic and archaeological/bioarchaeological contexts.



Source: Prepared by the authors using AI-generated imagery created with Grok AI (2026).

CONCLUSION

In summary, the identification of features associated with tuberculosis in the field of forensic anthropology relies on the integration of classic lesions, such as Pott disease and tuberculous arthritis, with minor indicators validated in identified skeletal collections. The individualizing potential of these alterations, when assessed against antemortem documentation, underscores the need for the systematic incorporation of radiological assessment into protocols for the examination of human skeletal remains. Future studies integrating contemporary forensic series with advances in three-dimensional imaging are likely to further consolidate the role

of skeletal pathologies as ancillary tools for positive identification, in accordance with internationally established criteria in the field.

Finally, the available evidence indicates that, within forensic anthropological contexts, tuberculosis should be considered not only as an indicator of disease but also as a potential source of individualizing information when its skeletal manifestations exhibit sufficiently distinctive characteristics and can be compared with antemortem clinical and radiological documentation. Comparison of antemortem and postmortem examinations, particularly through computed tomography and three-dimensional reconstructions, may enhance the ability to demonstrate anatomical and morphological correspondences between lesions, as demonstrated in forensic cases involving skeletal tuberculosis.

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