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Grotta dei Pipistrelli: osteological evidence of a young adult individual (Lucca, Italy)

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Abstract. In 2003, the Grotta dei Pipistrelli cave near Casoli in the Val di Lima, Lucca, yielded a human skeleton alongside a 17th century coin and animal remains. Anthropological analysis of the remains enabled the reconstruction of the biological profile of a young adult, likely male, aged approximately 22 years and measuring 164 cm in height. Paleopathological analysis revealed skeletal changes mainly at muscle and tendon attachment sites, which are likely to have been caused by chronic biomechanical stress. Some oral pathologies were also identified. Dental pathologies such as caries, abscesses, and antemortem tooth loss may be indicative of a carbohydrate-rich diet, which is consistent with the rural apennine context of tuscany.

Keywords: physical anthropology, biological profile, sex determination, age-at-death estimation, paleopathology.

Introduction

The Grotta dei Pipistrelli (1244 LU; coordinates: EST 633666, NORD 4877773) is a cave system located 499 metres above sea level in the Val di Lima, near Casoli, Lucca (Fig. 1). First catalogued in 1995 (Speleotoscana, 1995), the cave system yielded archaeological and bioarchaeological remains during a speleological expedition conducted by the Federazione Speleologi Toscana in 2003. These remains were discovered behind a carefully arranged pile of stones forming a barrier at the end of a narrow tunnel (Fig. 2). Unfortunately, no information is available about the disposition of the remains in the site.

Upon removing the stones, the explorers accessed a small chamber containing the skeletal elements, a distinctive 17th century coin (a Grosso), and numerous faunal remains, mainly long bones and some microfaunal specimens. The chronological attribution of the coin was not performed directly by the authors, but was instead provided verbally by staff at the Museum of Natural Science of Gavinana. Based on their expertise and reference collections, they identified the object as a 17th century artifact.

The assemblage was initially entrusted to the Museum of Natural Science of Gavinana for conservation and study until 2024. After this date, the remains were transferred to the Department of Biology, Anthropology Laboratory, University of Florence. To date, no burials from this chronological and geographical context have been published, and no bioarchaeological analyses have been carried out. The absence of archaeological and bioarchaeological research on such rural communities limits our understanding of their process of community formation, development, and persistence strategies.

Fig. 1. *Geographic map showing the location of Casoli, Val di Lima.*

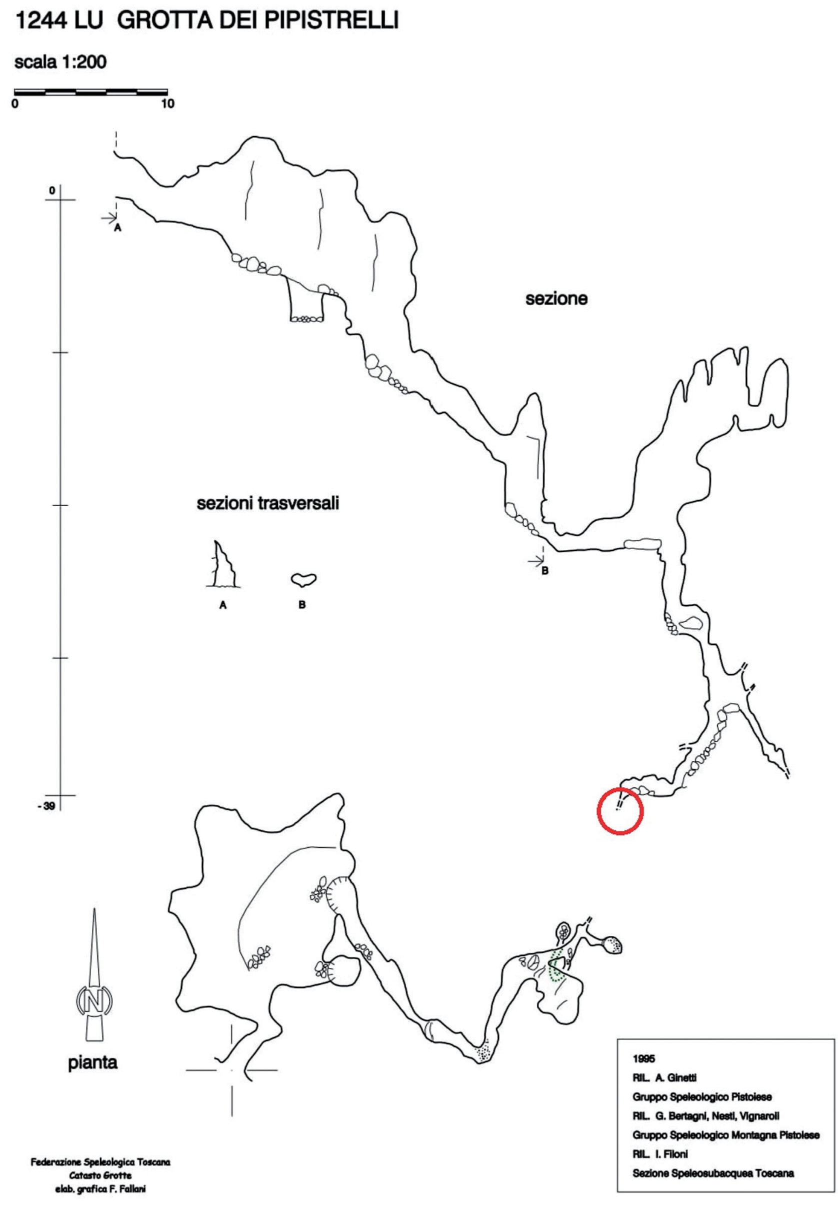

Fig. 2. *Cadastral section of the cave. The discovery site is circled in red.*

For this reason, we undertook a bioarchaeological analysis of the human remains as a first step towards a more comprehensive evaluation. Bioarchaeological and osteoarchaeological methodologies are essential tools for reconstructing the lifestyles and cultural practices of past populations (Soafer, 2012). The primary aim of this study is to provide a thorough anthropological evaluation of the skeletal remains excavated from Grotta dei Pipistrelli. Standard osteological protocols were applied to determine the minimum number of individuals represented in the assemblage. Reconstruction of the biological profile – including sex estimation, age at death, stature, and pathological conditions – serves as a valuable proxy for interpreting and reconstructing characteristics of past populations.

Although only a few bones appear to belong to one individual, this preliminary bioarchaeological analysis lays the groundwork for future archaeological and bioarchaeological investigations of Tuscan rural communities. Such studies will contribute to a deeper understanding of population dynamics and living conditions in early modern rural Tuscany. Our work follows established biological anthropology methodologies to reconstruct aspects of individuals' biological profiles. Macroscopic skeletal analysis is the most immediate and effective method for extracting biological and biocultural information from human remains. Even in the absence of contextual or documentary data, it allows researchers to infer demographic parameters, health status, and activity patterns (Rossi *et al.*, 2022).

Materials and methods

All skeletal remains were carefully cleaned and sorted into human and non-human categories. Human remains were restored wherever possible.

The minimum number of individuals (MNI) was established by first sorting the bones by element and side (left/right), then comparing them by length, thickness, and morphological characteristics, such as the dimensions of entheseal sites. The remains were then examined macroscopically, in accordance with standard physical anthropology protocols, following established methods for osteological analysis, morphological assessment, and metric evaluation (White and Folkens, 2005; Buikstra and Ubelaker, 1994).

Sex estimation was based on skeletal elements exhibiting the greatest sexual dimorphism, including the coxal bones, sacrum, cranium, and mandible (Buikstra and Ubelaker, 1994; Bruzek, 2002; Loth and Henneberg, 1996; Phenice, 1969).

Age at death was estimated using multiple indicators, including the degree of cranial suture closure (Meindl and Lovejoy, 1985), fusion of long bone epiphyses (Schaefer *et al.*, 2009), morphological characteristics of the pubic symphysis (Burns, 2015), and the stage of dental eruption (Ubelaker and Grant, 1989; AlQahtani *et al.*, 2010).

Stature was estimated using regression formulas proposed by Sjovold (Sjovold, 1990) and Trotter and Gleser (Trotter and Gleser, 1952), which were applied to the maximum length of the right femur – the only long bone available for complete measurement.

Pathological alterations of the skeleton and dentition were assessed through direct comparison with standard anthropological reference manuals (Ortner, 2003; Hillson, 1996).

Results

All anatomical regions of the skeleton are represented. (Fig. 3) The number and type of skeletal elements correspond to those of a single adult individual, with no duplicated or supernumerary bones observed. Paired elements exhibit consistent size, morphology, and robusticity. The overall preservation is moderate: most bones are present, though many are fragmented and partially covered by calcareous concretions.

Biological profile reconstructions

Sex estimation was carried out using the scoring methods proposed by Buikstra and Ubelaker (Buikstra and Ubelaker, 1994). The coxal bones yielded an average score of 4.2/5; the cranium, instead, gives an average score of 4.35/5. According to the reference standards, these values fall within the range associated with a probable male, as the observed morphological features are more consistent with male skeletal morphology than with female. The sacrum further supports this assessment: its overall morphology, including the extension of the auricular surface to the level of the third sacral vertebra, is typical of male individuals.

In contrast, mandibular metrics indicate an intermediate profile. The bimental breadth (41 mm) falls within the lower range of female values reported by Cole (42.75 ± 2.09 mm for females; 45.75 ± 2.74 mm for males), suggesting a possible female attribution (Cole *et al.*, 2017). The mandibular thickness (11.5 mm) aligns closely with male averages (11.54 ± 1.52 mm) but does not exclude a female at the upper end of the female range (10.52 ± 1.01 mm) (Cole *et al.*, 2017). The mandibular ramus height (58 mm) is more typical of males, exceeding the female mean reported by (55.40 ± 5.62 mm) and approaching the male mean (60.75 ± 8.71 mm) (Küchler, *et al.*, 2024). Additionally, the score assigned to the mental eminence (4/5) and the squared shape of the chin indicate a male individual (Buikstra and Ubelaker, 1994).

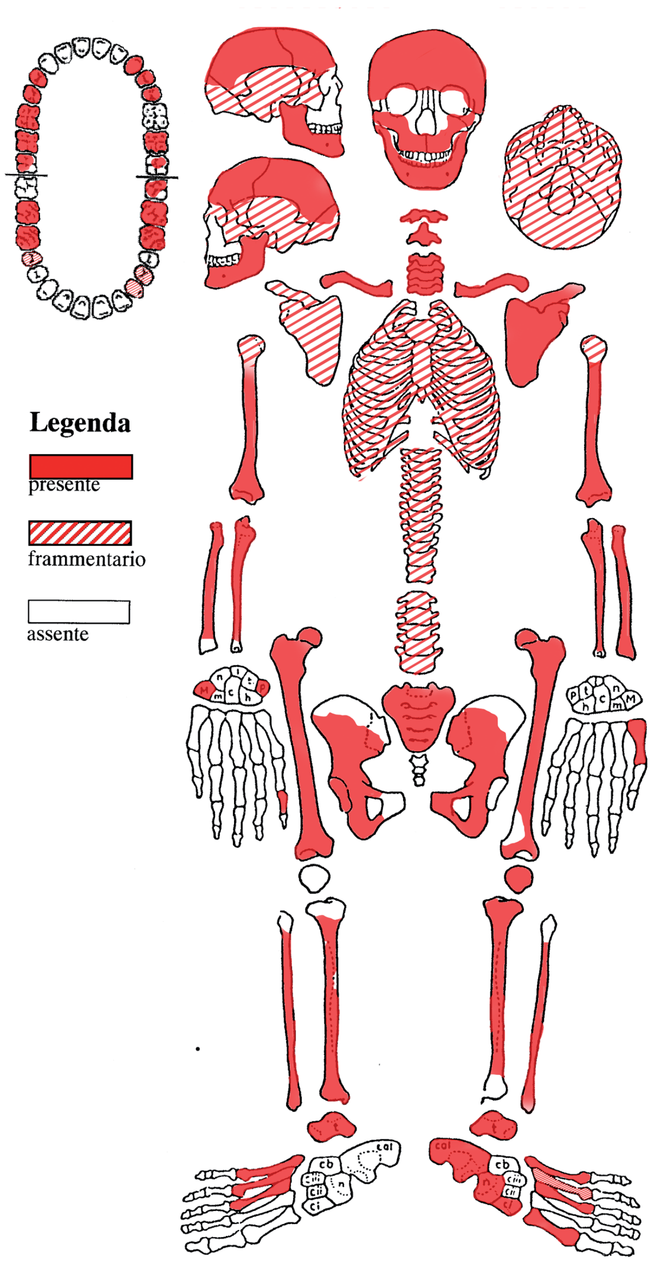

Fig. 3. *Anthropological field data sheet.*

To estimate age at death, several osteological indicators were considered. Dental development was assessed first (AlQahtani *et al*., 2010). No deciduous teeth were present. All third molars – except the lower right – are in the process of erupting, and dental wear is minimal. According to Ubelaker (Ubelaker and Grant, 1989), this stage corresponds to an estimated age of 18-21 years. Cranial suture closure provided a broader age range: the mean estimated age based on suture scores is 27,7 years, with a minimum of 18,6 and a maximum of 49,6 years. The sacrum has not yet fused at the S1-S2 junction, a condition typically observed in individuals around 25 (Schaefer *et al*., 2009, 120). Finally, the morphology of the pubic symphysis corresponds to an age range of 15-24 years. By cross-referencing these indicators, the estimated age at death is approximately 22 years.

Based on a femoral length of 44,4 cm, the estimated living stature is 165,1 ± 4,49 cm using the formula by Sjovold. According to the Trotter and Gleser formula for white males, the estimated stature is 167,1 ± 3,7 cm. (Trotter and Gleser, 1952; Sjovold, 1990).

Bones Pathologies

The cervical vertebrae exhibit slightly compressed and asymmetrical neural arches. The single available thoracic vertebra has a spinous process that is strongly oriented to the right. (Fig. 4) The right clavicle displays a porotic groove at the sternal end, measuring 2 cm in length, 1 cm in width, and 0.4 cm in depth. (Fig. 5)

A similar modification is observed on the left clavicle; however, in this case, the sternal end is fragmented, which allows only partial observation of the alteration. The right humerus has a superficial lesion on the anterior surface of the diaphysis near the proximal epiphysis. It measures approximately 4.5 cm in length and 2 cm in width, and shows cavitations and evidence of bone surface remodelling. (Fig. 6)

In the lateral-medial view, the left ulna displays a curvature along the diaphysis, forming an S-shaped deviation. The dorsal surface of the sacrum, particularly its inferior portion, has an irregular bone surface with a fibrous texture. The right patella shows localized ossification at the apex, at the site of tendon attachment. (Fig. 7).

A small ossified formation is visible on the articular surface of the right tibial *plateau*. The distal diaphysis of the right fibula, just proximal to the malleolar fossa, shows an area of surface irregularity and bone remodelling.

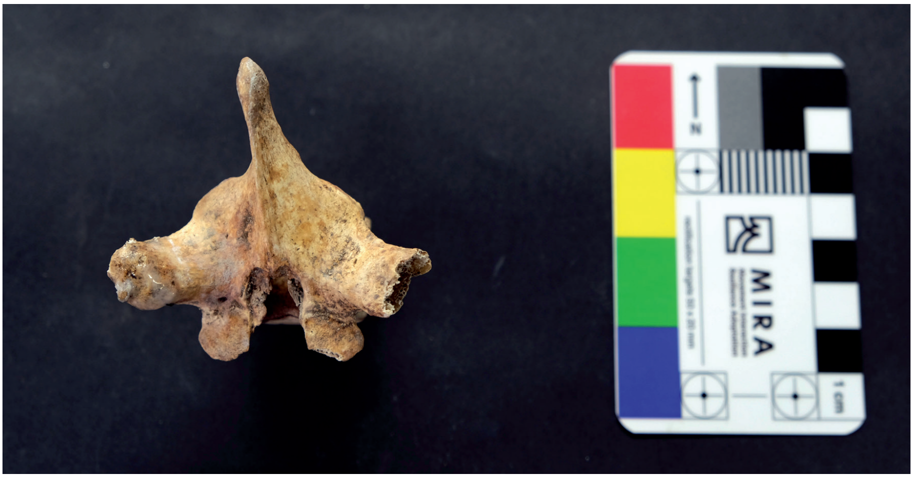

Fig. 4. *Thoracic vertebra. Spinous process visibly inclined.*

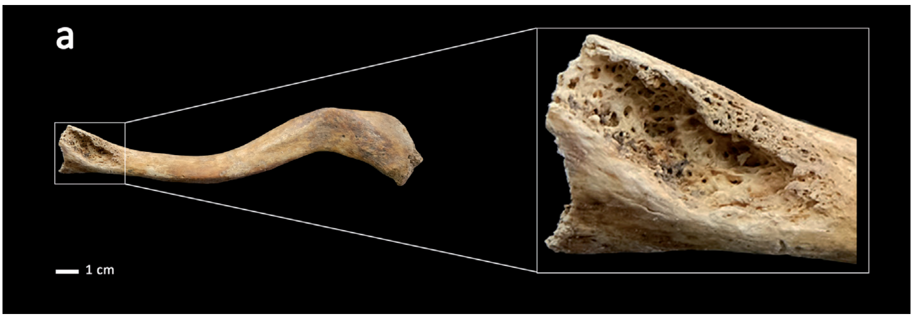

Fig. 5. *Right clavicle with detailed view of the enthesopathic lesion.*

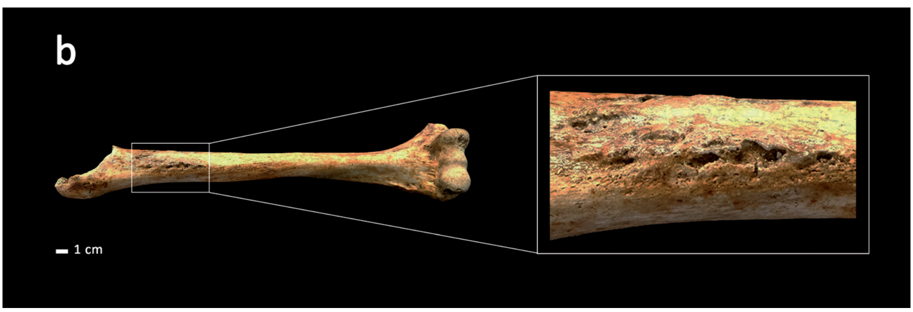

Fig. 6. *Right humerus with detailed view of the enthesopathic lesion.*

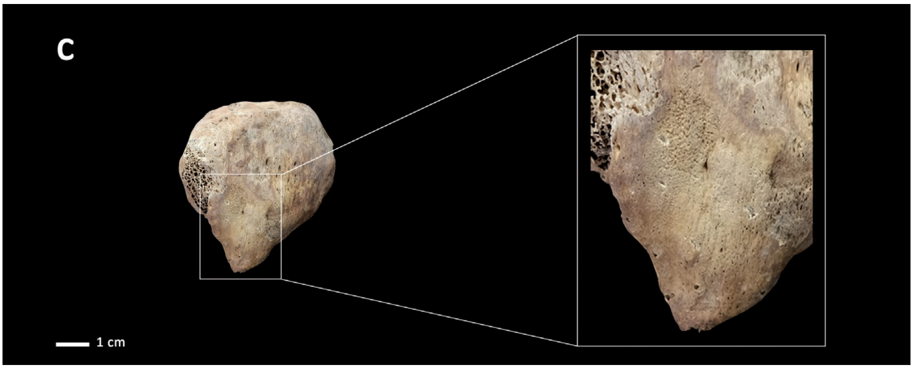

Fig. 7. *Left patella with detailed view of the ossified apex.*

Dental Pathologies

The anatomical nomenclature of the dentition follows the system used in Human Osteology (White *et al.*, 2011, 103).

In I_2L, C_1L, and P_4R, the crowns are missing, but the roots are still present. M_1R exhibits enamel wear on the mesial surface. M_2R shows a small cavitation on the labial surface. M_1L presents an alteration of the enamel layer on the mesial surface. At the level of the P_4L alveolus, slight bone remodeling is visible, with diffuse porosity. In the maxilla, at the level of the M_1L alveolus, the bone appears porous; the cavity is wider than expected and displays cavitations in its deeper portion.

Discussion

Based on the collected data, it can be confidently stated that the remains recovered from Grotta dei Pipistrelli belong to a single individual, a young adult (mean age: 22,6 years), probably male, with an estimated stature of approximately 166,1 ± 4,1 cm. Due to the fragmentary nature of the remains, the analyses conducted were necessarily limited, as only a few bones are completely intact. It is important to point out that many elements essential for sex estimation, such as much of the cranial vault and a substantial portion of the pelvic bones, are absent. Furthermore, the lack of comparable individuals from the same area makes the assessment of sex more problematic.

The individual was dated by radiocarbon analysis, conducted at LABEC – Laboratory of Nuclear Techniques for the Environment and Cultural Heritage, Florence Section, which places him in a period between 1480 and 1800 (Fig. 8). Although this range is relatively broad, a coin was found in association with the remains. According to an expert at the Gavinana Museum, the coin can be temporally assigned to the 17th century, which falls within the radiocarbon date range. This information was provided verbally, and no further data are available.

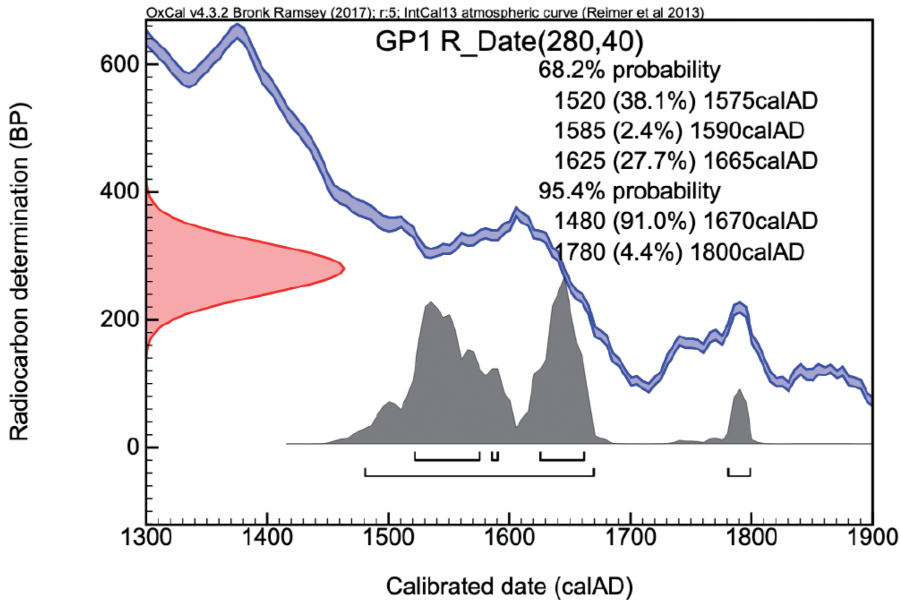

Fig. 8. *Radiocarbon analysis yielded by the LABEC.*

A detailed paleopathological examination of the individual revealed multiple alterations, which were investigated to assess the presence of various pathologies. The right humerus displays a 4,5 x 2 cm area of cortical alteration with cavitations and bone remodeling on the anterior diaphysis, close to the insertion of the deltoid muscle. The right patella exhibits localized ossification at the apex, corresponding to the origin of the patellar tendon, while a small ossified formation is present on the tibial *plateau* of the right tibia.

Additional findings include a rhomboid-shaped depression at the sternal end of the right clavicle measuring approximately 2 x 1 x 0,4 cm; surface irregularities and remodeling near the malleolar fossa of the right fibula, and a fibrous, non-uniform texture in the lower dorsal portion of the sacrum. Left ulna shows an S-shaped curvature of the diaphysis; a spinous process of a one lumbar vertebra deviated to the right, and the neural arches of the cervical vertebrae are slightly compressed and asymmetric. These changes are most often associated with repetitive mechanical stress at the attachment points of muscles and ligaments, or with some pathological processes (Villotte *et al.*, 2010). Such bone modification is sometimes associated with infectious deseases such as tuberculosis, brucellosis, and syphilis. However, these diagnoses were excluded because the observed alterations are not consistent with the classical anatomical site of these infections, which particularly affect the vertebral column, facial skeleton, and extremities, and only exceptionally localize in the long bones – the principal sites involved in this case (Aufderheide and Rodrìguez-Martìn, 2006, 118, 192).

Neoplastic and osteomyelitic processes were also considered, as they can form cavitations, particularly in the clavicle and humerus. These conditions do not have a predilection for specific skeletal regions and do not account for the exclusive localization of lesions at enthesis or near articular surfaces (Aufderheide and Rodrìguez-Martìn, 2006). Instead, the pattern observed here – alteration restricted to areas of muscle and ligament attachment, and periarticular ossification – is more likely a consequence of chronic, repetitive mechanical stress (Jurmain *et al.*, 2012; Reitsema and McIlvaine, 2014). For example, the ossification at the apex of the patella can be a reflection of chronic patellar tendon inflammation, similar to the formation of osteophyte, often seen in arthritis (Mann and Hunt, 2005). However, the absence of further arthritic changes and the relatively young age of the individual preclude a systemic arthritic process.

In conclusion, the accumulation and distribution of the osseous changes seen in this individual are best explained by localized biomechanical stress, rather than by systemic infectious or neoplastic processes (Ortner, 2003).

This is consistent with broader historical trend for early modern Tuscan history, where the majority of the rural population engaged in physically demanding agricultural labor with minimal technological innovation or mechanization (Alfani, 2007; Mocarelli and Ongaro, 2019). Even though we cannot be sure what job this individual was employed as, or what they were doing throughout their life, the background as a whole suggests heavy lifting and long physical work was the standard for the rural population (Ortner, 2003).

While the teeth are only slightly worn, as would be expected for a relatively young individual, they still bear extensive pathological signs. Two abscesses were identified, one affecting the left second premolar (P_4L) and the other the left first molar (M_1L); the latter abscess was in an advanced state, and most likely resulted in antemortem tooth loss. The majority of the unrecovered teeth were lost post-mortem since there is no indication of alveolar modification. Multiple carious lesions and dental calculus deposits provide evidence of a carbohydrate-rich diet (Larsen *et al.*, 1991, 202), which is common in early modern contexts, and is also coherent with the living situation of a 17th century foothill population from Tuscany (McC. Netting, 2010).

The chronological framework associated with this remains corresponds to a period of pronounced demographic and economic instability in the Tuscan Apennines. Between the late 15th and 18th centuries, rural communities in such regions as the Val di Lima were frequently affected by epidemics, fluctuating population densities, and subsistence challenges (McArdle, 2005, 42-47). Residents of these mountainous areas often relied on cereal cultivation and pastoralism, resulting in a diet rich in carbohydrates but limited in protein sources. Notably, in the Pistoia area, historical and environmental data suggest a preferential consumption of chestnuts, as the region is characterized by extensive chestnut groves (Fornaciari, 2015). This dietary pattern, centered around chestnuts as a carbohydrate staple, would have contributed to the dental pathologies seen, and is consistent with the broader subsistence patterns among rural Apennine group in the early modern era.

Alfani also adds that the population regime of the centuries was marked by repeated periods of famine, epidemic, and economic hardship. These not only impacted on population structures, but also shaped daily life and labor conditions. The repetitive nature of agricultural crises, as well as the absence of sensational technological breakthroughs, rendered rural populations particularly susceptible to environmental fluctuations and resource scarcity (Alfani, 2007). These challenging conditions likely increased the physical demands placed on individuals, a fact supported by skeletal evidence of musculoskeletal stress, such as ossification at tendon attachment sites and reactive bone modifications. This reflects a lifestyle characterized by intense physical activities (Fornaciari, 2015).

The results presented here provide a valuable foundation for further multidisciplinary investigation. Stable isotope analysis ($\delta^{13}C$, $\delta^{15}N$) could clarify dietary patterns and mobility, helping to confirm the hypothesised reliance on carbohydrate-rich foods and to identify possible consumption of animal or marine proteins. Analysis of dental calculus could provide further insights into oral microbiota, health status, and exposure to pathogens.

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