Different in death: different in life? Diet and mobility correlates of irregular burials in a Roman necropolis from Bologna (Northern Italy, 1st-4th century AD)

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Abstract

The study of migration within the Roman Empire has been a focus of the bioarchaeological and biogeochemical research during the last decade. The possible association of diet and sex, age, and funerary treatment during the 1st-4th centuries AD have been extensively explored in Britain, and Central-Southern Italy. Conversely, no knowledge is available about these processes for the North of the Italian Peninsula. In the present work we analyse a set (N=16) of Roman inhumations from Bologna (Northern Italy, 1st-4th c. AD), some of which are characterized by unusual features (prone depositions, transfixion of the skeleton by iron nails). Analysis of strontium, oxygen, nitrogen, and carbon isotopes is used to test for the possible correlation between funerary treatment, geographic origin, and diet. Here we provide the first biogeochemical data for a Northern Italian Imperial sample, wherein our results show no clear association between these variables, suggesting that funerary variability, at least in the analysed context, was shaped by a variety of heterogeneous factors, and not a representation of vertical social differences or differential geographic origins

Keywords: Isotopes; Irregular burials; Diet, Mobility; Roman Empire; Bologna; Italy

1. Introduction

1.1. Roman mobility and irregular burial practices

The widespread control exercised by the Roman Empire facilitated high levels of mobility through the establishment of peaceful conditions and dense road networks throughout newly acquired areas (de Ligt and Tacoma 2016; Tacoma 2016). The resulting migratory and social processes have long been a major topic of Roman studies, as demonstrated by the large array of studies focusing on the archaeological and biochemical signatures of cultural contact and migration which took place in Western Europe and the Near East between the last centuries BC-first centuries AD (de Ligt and Tacoma 2016; Eckardt 2010; Eckardt et al. 2009, 2010, 2014, 2015; Evans et al. 2006; Killgrove 2010a,b; Killgrove and Montgomery 2016; Noy 2000, 2010; Prowse et al. 2007, 2010; Stark 2017; Tacoma 2016). Quantitative studies of migratory patterns during the Roman Empire have been calculated using mainly two types of data: historical records including census and epigraphic data, and stable isotope ratios, largely represented by studies focusing on $^{87}Sr/^{86}Sr$ and $\delta^{18}O$. The resulting estimates, however, largely deviate from each other. Census and epigraphic data point to a range of nonlocals between 40% of adult males in Italy (Scheidel 2004), 5% of free citizens in Rome and overall Gaul (Wierschowski 1995), and 1-5% in Spain (Haley 1991). A somewhat different scenario is depicted by isotopic studies on single cemeteries, resulting in values of nonlocals reaching 23% in *Portus Romae* (Central Italy - Prowse et al. 2007), 30% in both Saintes (Western France - Stark 2017) and Neuburg/Donau (Southern Germany - Schweissing and Grupe 2003), and percentages of non-locals above 40% for York, Catterick, Gloucester, and Lankhills (Eckardt et al. 2010).

A relevant aspect of any migration process is the resulting interaction between the migrants and the host society (Berry 1997; see also Burmeister 2000; Grabska 2006; Phinney et al. 2001). Differential patterns of social integration, assimilation or segregation are of interest not only due to their cultural (e.g. linguistic) correlates, but also due to their effect on biological aspects of a population, e.g. changes in genetic polymorphism and genetic heterozygosity (Cavalli-Sforza et al. 1994; Creanza et al. 2015; Henn et al. 2012; Levitt 1998; Pagani et al. 2016; Ramachandran et al. 2005; Reyes-Centeno et al. 2014). Therefore, analyses involving the mechanisms and patterns of migratory processes of the past are essential to the development of a comprehensive understanding of cultural and biological exchange and the subsequent influence of migration on microevolutionary processes.

The last decade has witnessed an increasing availability of comparable osteological, archaeological, biomolecular, and, in particular, biochemical data. The abundance of data have subsequently stimulated a number of multidisciplinary research projects focusing on various aspects of mobility during the Roman Empire, with a wide range of contexts including Britain, Italy, and Germany (e.g. Eckardt et al. 2010, 2014; Emery et al. 2018a; Emery et al. 2018b; Killgrove 2010b; Killgrove and Montgomery 2016; Prowse et al. 2010; Schweissing and Grupe 2003; Stark 2017).

Results from these studies are interesting due to their consistency with both processes of cultural assimilation and appropriation, as demonstrated by general lack of contrasts between immigrants and locals in either funerary treatment or lifestyle, and in some cases, by an inverse correlation between skeletal and archaeological proxies of mobility. Therefore, further research is needed to explore the existence of any relationship between geographic origin and funerary treatment and to further understand alternative burial practices within the Roman Empire.

The existence of interments characterized by unusual burial treatments of the individual that do not conform to what is known as normative burial practices within the respective cultures is a well-known phenomenon known to occur in the first centuries AD (but not only - see Murphy 2008; Reynolds 2009; Rittershofer 1997). For Roman times, burials described as *deviant* or *irregular* generally feature prone depositions, traces of mutilation of the corpse or skeleton, and burial artefacts such as amulets or other types of objects of possible ritual meaning (Alfayé Villa 2009a, 2009b; Arcini 2009; Crerar 2016; Milella et al. 2009, 2010, 2015; Pauli 1975; Philpott 1991; Taylor 2008; Watts 1998). Interpretations of these findings are still largely influenced by the link between uncustomary funerary treatments and perceived social deviancies established by Saxe (1970). This perspective is also at the basis of the recurrent interpretation of irregular funerary treatments as the by-product of fear toward the dead (e.g. Reynolds 2009; Tsaliki 2008). A more nuanced approach focuses on the link between funerary practices and patterns of social membership, social differentiation, and cultural transmission. An interesting interpretation is provided by Crerar (2012, see also Crerar 2016), who focuses on 59 Romano-British sites from the Fen Edge, Dorchester, and London. The substantial lack in each region of clear funerary, demographic, and paleopathological differences between decapitated individuals and the rest of the population suggests that decapitation was not a manifestation of social ostracism. Rather, this ritual was probably just a facet of the accepted funerary variability for a given social group. Watts (1998) argues for a link between alternative position of the body and religious changes in Roman Britain. Specifically, prone inhumations are interpreted as the need to re-affirm local religious traditions against the spread of exotic cults (i.e. Christianity). The association between pagan rites and alternative burial treatment, and the implicit link between Christianity and normal depositions has been however recently criticized by Crerar (2012, 2016). The lack of homogeneity of Romano-British Christian burials, the lack of textual evidence about related funerary prescription, the influence of status differences on burial variability, and the problematics affecting straightforward interpretations of funerary custom from an ethnic perspective (see Petts 2016; Pearce 2010, 2016) further complicates this type of discussions. Finally, after having statistically analysed a large dataset of Roman irregular burials, Milella and colleagues (2015), link their variability and geographical patterns to both political and biocultural processes characterizing Western Europe between the 1st-5th centuries AD.

A topic requiring further investigation (but see Eckardt et al. 2009; Killgrove 2010b) is the presence of a common pattern between irregular burial practices and the isotopic indicators of mobility ($\delta^{18}O$, $^{87}Sr/^{86}Sr$) and diet ($\delta^{15}N$ and $\delta^{13}C$) from dental and bone samples.

1.2. Isotopic reconstruction of mobility and diet

1.2.1. $\delta^{18}O$ and $^{87}Sr/^{86}Sr$

The rationale for the use of $\delta^{18}O$ and $^{87}Sr/^{86}Sr$ analyses in mobility studies is their correlation with geology and climate, and, hence, geographic location. Specifically, $\delta^{18}O$ values are influenced by a set of variables including latitude, distance from the coast, altitude, and humidity. $^{87}Sr/^{86}Sr$ values, on the other hand, reflect both the specific geological composition and the age of the bedrock (Brown and Brown 2011; Katzenberg 2007; Levitt 1998; Montgomery 2010; Sealy et al. 1991). Through the ingestion of local foods and water, the isotopic signal of the immediate environment is absorbed and stored in dental and skeletal tissues. Accordingly, deviations in the isotopic signal of the enamel from that characterizing the burial location can (cautiously, since there are further influencing factors like dietary preferences – see Montgomery 2010) be interpreted as indicative of nonlocal origins.

1.2.2. $\delta^{13}C$ and $\delta^{15}N$

The application of $\delta^{13}C$ and $\delta^{15}N$ analysis helps do characterise the main (protein) components in human diet (Ambrose and DeNiro 1986; Brown and Brown 2011; DeNiro and Epstein 1981; Katzenberg 2007; Schoeninger 1985; Schoeninger 2011). Due to their specific photosynthetic pathways, C_3 and C_4 plant biomasses differ in their $\delta^{13}C$ values (Ambrose et al. 2003; Bender 1971; Cerling 1984; Griffiths 1992; Peterson and Fry 1987). C_3 plants tissues are generally depleted in ^{13}C relative to ^{12}C and have $\delta^{13}C$ values between -35 and -20‰. C_4 plants tissues, on the other hand, are less ^{13}C-depleted, resulting in less negative $\delta^{13}C$ values from -14 to -9‰ (Brown and Brown 2011). Since $\delta^{13}C$ collagen values of humans and animals are proportional to the isotopic signal from the base of the food chain (plants), they allow estimates of the percentage of C_3 vs.C_4 plants in the diet. About nitrogen, ^{15}N undergoes a significant enrichment (3 to 5‰) for each trophic level in a food chain (Hedges and Reynard 2007). $\delta^{15}N$ collagen values can therefore be used to evaluate the trophic system of an animal, and, in the case of humans, to estimate the relative amount of animal proteins in the diet (Katzenberg 2007; Laffranchi et al. 2016; Schoeninger and DeNiro 1984). Although differences in nutrition is the main source for varying $\delta^{13}C$ and $\delta^{15}N$, it needs being kept in mind that physiological factors, e.g. nutritional stress and starvation, also influence the carbon and nitrogen isotope signatures in human bone collagen (Beaumont et al. 2013; Crowder et al. 2019; D'Ortenzio et al. 2015; Fuller et al. 2004, 2005; Hobson 1993; Mekota et al. 2006; Reitsema 2013; Reitsema and Holder 2018; Walter et al. 2018).

1.2.3. Sampling material

Due to their different chemical composition and resistance to isotopic changes during life or after burial, enamel and bone collagen are used for different research purposes: $\delta^{18}O$ and $^{87}Sr/^{86}Sr$ are usually investigated in tooth enamel, whereas bone collagen is routinely used for the analysis of $\delta^{15}N$ and $\delta^{13}C$.

Human teeth act as valuable archives of information as they store the isotopic signal of the place where an individual lived during tooth mineralization. This signal accumulates roughly from perinatal time to 3 years for first permanent molars (M1), 2 to 5 years for first permanent premolars (PM1), 2.5 to 7 years for second permanent premolars (PM2), 3 to 7 years for second permanent molars (M2), and 9 to 16 years approximately, although variable for third permanent molars (M3) (Knipper 2011, fig. 8.3). The isotopic signal within dental enamel remains relatively unaltered and thereby provides isotopic information of the individual's life during the time of dental development (Bentley 2006). Conversely, due to bone remodelling, skeletal tissues provide an isotopic insight into the last years of someone's life (diet and ingested water characterizing the isotopic ratios of the newly formed bone). Variation in the rate of bone remodelling and turnover is known to occur between skeletal elements and therefore has important consequences when interpreting isotopic data. For example, ribs show a relatively fast remodelling rate and are consequently particularly informative about the diet during last years of someone's life (Fahy et al. 2017). In contrast, bone from the femoral shaft exhibits a much slower turnover rate and therefore, isotopically reflects a chronological span larger than 10 years and including adolescence (Hedges et al. 2007).

Here, we explore for the first time the possible link between diet, mobility, and irregular funerary practices in Northern Italy, by focusing on an Imperial Roman context, i.e. the necropolis *Nuova Stazione dell'Alta Velocita'* - henceforth TAV - in Bologna. Specifically, we investigate the possible association between irregular funerary treatment and social differentiation by testing the following hypotheses:
1) Irregular funerary practices at TAV are the expression of social differentiation, leading to a correlation between the diet of an individual during life and the type of their funerary treatment.
2) Irregular funerary practices at TAV are the expression of social differentiation stemming from the exotic origin of an individual.

2. Material and methods

2.1. Archaeological context

The necropolis TAV was excavated between 2004 and 2007, in an area corresponding to the northern suburb of the ancient city of *Bononia*. The cemetery (Figure 1) includes a total of 183 cremations and 40 inhumations, mostly dating to the 1st century AD (Cornelio Cassai and Cavallari 2010; Milella et al. 2010). Inhumations are represented by simple pits, pits provided with brick covers, brick structures, and/or coffins, with only one case (burial 89) presenting traces of a wooden coffin. Overall, these burials show features consistent with the Roman funerary customs usually observed for the first centuries AD in the Italian peninsula (e.g. Bissoli 2001; Buccellato and Capitanio 1997; Small 2007). The individuals are buried supine, extended and (at least for adults) provided with a variable amount of grave goods. Six burials (76, 89, 103, 109, 161, and 244), stand out due to a suite of unusual features including the prone position of the individual, and/or skeletal traces of purposeful disturbance of the remains (Table 1).

2.2. Morphological analysis

Morphological analysis was conducted on the individuals that were included in the isotopic study (N=16, Table 1). The number and choice of these individuals were based on a) the available funding for the study, b) the relative preservation of the dental and skeletal remains, and c) our attempt to collect a sample relatively balanced in terms of sex and age-at-death.

Adult sex and age at death were estimated according to Ferembach et al. (1980), and Buikstra and Ubelaker (1994). Adults (≥ 20 years old) were then classified according to the following age classes: young adults (20-34 years old), mature adults (35-49 years old), and old adults (≥50 years old). Subadult age-at-death was estimated on the basis of development and eruption of deciduous and permanent dentition, and degrees of epiphyseal fusion (Scheuer and Black 2000; Ubelaker 1989). In order to check for a possible association (or lack thereof) between irregular funerary treatment and the presence of pathological changes of bone and/or teeth (see also Southwell-Wright 2014), the latter was evaluated following Ortner (2003). Presence and type of skeletal traumatic lesions were analysed according to the criteria of Lovell (1997), both microscopically (Leica S8AP0) and macroscopically with the aid of a magnifying glass. If lesions were identified, their time of occurrence (intra vitam, peri mortem - around the time of death - vs. post mortem - after completed skeletonization) was indirectly estimated on the basis of the relative plasticity of the bone and its reaction to the biomechanical strain resulting from

the traumatic event. Trauma were classified as intra vitam in they showed any sign of osseous healing process. Features consistent with a peri mortem traumatic event included: presence of a bevelling on endocranial surface corresponding to the point of entrance (in cases of penetrating cranial injuries), smooth fracture margins with oblique angles, fracture surfaces showing the same colour of the surrounding bone, presence of secondary linear and concentric radiating fractures, and of bone fragments adhering to the fracture margin (Berryman and Haun, 1996; Fibiger et al. 2013; Knüsel, 2005; Sauer 1998).
Archaeothanatological features of each burial (i.e. primary vs. secondary deposition, presence and type of environmental disturbances) were reconstructed using the criteria of Duday (2006) on the basis of archaeological reports, field images, and extensive discussions with the archaeological personnel.

2.3. Carbon and nitrogen isotope analysis

15 individuals were analysed for their carbon and nitrogen isotope compositions (Table 2). These include 5 irregular burials (TAV 76, 89,103,109, and 161). The sixth irregular burial (TAV 244) was not sampled due to scarcity of loose bone fragments associable with confidence to this individual.
Collagen extraction followed the methodology outlined in Longin (1971), Ambrose (1990), and Oelze et al. (2011) with the exclusion of the ultrafiltration step of which the benefit is considered uncertain (cf. Jorkov et al. 2007; Sealy et al. 2014). The bone samples were cut and the surfaces removed using dental cutting and milling equipment. Between 130 and 780 mg of sample material was demineralized in 10 ml of 0.5 M HCl at 4°C for two weeks with daily shaking, occasional exposition to room temperature and an acid bath change after one week. Samples were then rinsed with ultrapure water to restore neutral pH before treatment with 10 ml of 0.1 M NaOH at 4°C for about 24 hours to remove any humic substances. After rinsing to reach neutral conditions, 4 ml of ultrapure water and 200 µl of 0.5 M HCl were added and the samples gelatinized at 70°C for 48 hours. Finally, the solution containing the dissolved collagen was filtered using Ezee Filter separators (Elkay, UK) with pore size 60-90 µm to remove any remaining particulate organic remnants, frozen at -20°C, and lyophilized for 48 hours. Between 0.5 and 1 mg of freeze-dried sample were weighed into tin capsules, and their carbon and

nitrogen isotopic compositions ($\delta^{13}C$, $\delta^{15}N$) were determined by Elemental Analysis – Isotope Ratio Mass Spectrometry (EA-IRMS) using an INTEGRA2 instrument (Sercon Ltd., Crewe, UK) at the Department of Environmental Sciences, University of Basel. All samples were analysed in duplicate, except for TAV 23 and 76 which gave only one result. The raw data were isotopically normalised using two-point calibrations based on the EDTA laboratory standard and IAEA-CH-6 for $\delta^{13}C$ and on the EDTA laboratory standard and IAEA-N-2 for $\delta^{15}N$ (cf. Paul et al. 2007). Based on these isotopic standards the analytical error (1σ) was better than ± 0.25 ‰ for $\delta^{15}N$ and better than 0.1 ‰ for $\delta^{13}C$. Carbon and nitrogen isotope compositions are expressed as δ values relative to VPDB and AIR-N_2, respectively. Collagen preservation and purity was checked following DeNiro (1985), Ambrose (1990), van Klinken (1999), and Dobberstein et al. (2009). All but two samples (TAV 12 and 109) fulfilled the criteria for being included in further discussion.

Animal bone was not available for this study. Therefore, we compared our results with published isotopic data for other Italian Roman contexts (Craig et al. 2009; Killgrove and Tykot 2013, 2018; Martyn et al. 2018; Prowse et al. 2004; Rutgers et al. 2009; Scorrano et al. 2014; Tafuri et al. 2018).

2.4. Oxygen and strontium isotope analysis

15 individuals were analysed for their oxygen and strontium isotope ratios. This sample does not include TAV 76 (burial with nails) due to the lack of teeth available for analysis. With two exceptions (TAV 10 and 12: both subadults) tooth enamel from two teeth per individual was sampled (Tables 3 and 4). This normally includes the first molars (first premolar in the case of TAV 9b) and third molars (second molars in the case of TAV 6, 14, and 23; second premolar in the case of TAV 109). For simplicity we will henceforth refer to these samples as *first and second dental samples*.

Dentine was sampled for nine individuals in order to establish the baseline $^{87}Sr/^{86}Sr$ value (see below). Enamel samples representing the complete growth axis was removed using a flexible diamond-impregnated dental disk and hand drill. The inner and outer surfaces of the enamel chips were then treated with a dental burr and all samples were cleaned in an ultrasonic bath to remove any adhering contamination. Also, dentine samples were cleaned thoroughly from all sides using a dental hand drill to assure that any enamel remains or contamination is removed. For carbon and oxygen isotope analysis the samples were ground to powder. Approximately 2 mg of the powdered tooth carbonate samples were weighed into 12 ml exetainers (Labco Limited, Lampeter, UK). The exetainers were then purged with helium and the contained carbonate samples were reacted with 100% H_3PO_4 at 70 °C for 90 minutes. The carbon and oxygen isotope compositions of the generated CO_2 were determined at the Department of Environmental Sciences, University of Basel using a Gasbench II coupled to a Delta V Advantage mass spectrometer (Thermo Fisher Scientific, Bremen, Germany). Carbon and oxygen isotopic ratios were calibrated using international carbonate isotope standards NBS19 and LSVEC and reported in δ-notation as $\delta^{13}C$ and $\delta^{18}O$ relative to VPDB (Vienna Pee Dee Belemnite), respectively. Based on internal and external standards precision is typically $\leq \pm 0.15$ ‰ for both $\delta^{13}C$ and $\delta^{18}O$.

To approach geographical localization of the sample, carbonate $\delta^{18}O$ values (VPDB) were subsequently converted to the oxygen isotopic composition of drinking water ($\delta^{18}O_{DW}$ vs. VSMOW) using the equation provided by Chenery et al. (2012): $\delta^{18}O_{DW}= 1.590 \times \delta^{18}Oc - 48.634$, and further compared with published $\delta^{18}O$ data from precipitation across Italy (Giustini et al. 2016).

For strontium isotope analysis, about 6-30 mg of tooth enamel from each individual were mechanically cleaned using a dental burr to remove any adhering dentine or contaminants. Dentine was reversely cleaned from enamel remains. Samples were then cleaned in 18.2 MΩ cm (ultrapure) water in an ultrasonic bath. Samples were dissolved in 1 ml 7N HNO_3, dried down and re-dissolved in 2 ml 3N HNO_3. Aliquots representing 3 mg of enamel (or dentine) were then subject to ion exchange chromatography. Strontium was separated using 70 µl of Eichrom Sr spec resin (50–100 µm) columns, the resin was first cleaned with alternate washings of 3 ml 3N HNO_3 and 3 ml ultrapure water. Following conditioning with 1.5 ml 3N HNO_3 the samples were loaded as 0.5 ml aliquots. Samples were washed with 2.2 ml 3N HNO_3 before strontium was eluted in 1.5 ml ultrapure water. After separation, the Sr-containing eluate was dried down and loaded onto outgassed Ta filaments with a Ta activator solution. $^{87}Sr/^{86}Sr$ was analysed using a ThermoFisher Scientific Triton Plus Thermal Ionization Mass Spectrometer (TIMS) at the

University of Southampton using a static routine with amplifier rotation with a ^{88}Sr beam of 2V. The long-term average for NIST SRM987 on the instrument was 0.710245 ± 0.000027 (2sd) on 214. The average column blank was 0.2ng, replicates of NIST SRM987 which had been though the column chemistry averaged 0.710230 ± 0.000017 on 5 which agrees within error of the unprocessed standards.

The choice of the most suitable baseline sample for characterizing the local biologically available strontium is a matter of discussion (e.g. Bentley 2006; Maurer et al. 2012; Price et al. 2002). Lacking animal and modern vegetation samples, we used diagenetically altered dentine from human dental samples to estimate a value for the biologically available strontium at the burial place. In contrast to tooth enamel, dentine is highly susceptible to Sr isotope exchange with water in the soils, and can thus be used as a proxy for the local $^{87}Sr/^{86}Sr$ baseline (Hoppe et al. 2003; Reitmaier et al. 2018; Trickett et al. 2003). $^{87}Sr/^{86}Sr$ values were further compared with the Sr isotope map of Italy realized by Emery and colleagues (2018b).

Acknowledging the difficulties of using published rainfall data in paleomobility studies (Lightfoot and O'Connell 2016), and in order not to overestimate the frequency of nonlocals, individuals were considered nonlocals if their $\delta^{18}O_{DW}$ and $^{87}Sr/^{86}Sr$ values fell outside $\pm 3MAD_{norm}$ (median absolute deviation from the median) of the sample (Lightfoot and O'Connell 2016).

Comparison of isotopic values between sexes, age classes, and funerary features were performed in the package "coin" (Hothorn et al. 2008) for R version 3.5.1 (R Core Team 2018) using Wilcoxon tests with Monte Carlo simulation (10.000 resamplings) and setting alpha = 0.05 (Tables 5 and 6).

3. Results

3.1. Osteological and archaeological features

Table 1 summarizes the demographic and archaeological features of our sample. Irregular burials are represented only by adults, with no clear bias in sex representation. Irregular features include both the prone position of the individual (TAV 89, 103, 161, and 244) and the association between the skeleton and foreign objects (TAV 76, 109, and 244).

TAV 76 was characterized by the presence of at least 13 iron nails (the poor preservation of the metal not allowing the exact count of these items), for which size, morphology, and, especially, distribution are not consistent with an association to a coffin or other items (e.g. footwear). The nails were distributed on different anatomical regions including the cranium, the right wrist and mid-forearm, the sternum, and the right clavicle (Figures 2a and 2b). Both the skeleton and the nails were extremely degraded at the moment of discovery. This hampered a full assessment of their association. However, the block-lifting of the proximal portion of the right forearm allowed the direct observation of one of the two nails in this region. The nail penetrates the interosseous space perpendicularly, in a lateral-medial direction (Figure 2c). No traces of bone reaction were observed on the ulnar and radial shafts near the nail.

TAV 109 was characterized by the presence of 13 iron nails distributed on different anatomical regions: feet, left shoulder, and cranium (Figure 3a). A direct association of these objects with the skeleton was ascertained only for the cranium, where the nail was still *in situ* at the moment of excavation (Figure3b). Here, the good preservation of the parietal bones allowed a detailed study of the associated lesion. It presents an elongated morphology and irregular margins, and, endocranially, a slight bevelling (Figure 3c). TAV 244, a prone inhumation, is represented by the lower half of the skeleton (until the 4th lumbar vertebra) of a young adult female (Figure 4a). The partial preservation of the remains is likely due to a reduction of the burial in antiquity, as further suggested by the presence in the fill of mandibular and postcranial fragments (ribs, ulnae, clavicles). Based on colour, size, dental development, and dental wear these remains can be assigned to the individual TAV 244. A circular lesion with a diameter of c. 3 cm was present on the left ilium through which a glassy vessel was inserted (Figure 4b). The lesion, which reaches the iliac crest, is characterized by irregular margins, no traces of bone reaction, and an overall coloration homogenous with the surrounding bone (Figures 4c and d). In general, this group of burials is representative of the variability at TAV for type and amount of grave goods and burial type. Possible exceptions are represented by the two prone individuals TAV 89 and TAV 161 (Figure 5a and b). In the first case, the individual was provided with a wooden coffin (the only case at the site) and oriented North-South (a feature shared only by another 7 individuals). As for TAV 161, this is the only case where shoes (represented by two clusters of hobnails) were placed directly under the face of the individual.

No specific pathological features differentiate the irregular burials from the rest of the sample. The only exception to this trend is TAV 161 (prone), which shows a healed fracture on the distal third of the left ulna. Unfortunately, the fragmentation of the bone does not allow to discriminate the type of fracture (oblique vs. transverse), and the type of event possibly responsible for its production (accidental traumatic event vs. episode of interpersonal violence).

3.2. Isotopic analysis: $\delta^{13}C$ and $\delta^{15}N$

With the exception of TAV 12 and 109, which have a collagen yield of <1%, atomic C/N ratios fall inside the range of 3.2–3.4, and point to a good preservation of all remaining samples (DeNiro 1985) (Table 2).

$\delta^{13}C$ values range from -20.9 ‰ to -19.7‰ (VPDB), $\bar{x}$ = -20.3 ± 0.3‰. Compared to the tight clustering of $\delta^{13}C$ values, $\delta^{15}N$ values are rather widely spread, ranging from 7.3‰ to 11.3‰ (AIR), $\bar{x}$ = 9.1 ± 1.1‰.

Figure 6a shows the data for the TAV individuals together with those for the human and faunal comparative samples from Casal Bertone and Castellaccio Europarco (Rome, 1^{st}-3^{rd} century AD - Killgrove & Tykot 2013), St. Callixtus (Rome, 3^{rd}-5^{th} century AD - Rutgers et al. 2009), Lucus Feroniae (Rome, 1^{st}-3^{rd} century AD - Tafuri et al. 2018), Gabii (near Rome, 1^{st}-3^{rd} century AD - Killgrove & Tykot 2018), Isola Sacra (near Rome, 1^{st}-3^{rd} century AD - Prowse et al. 2004), Cosa (Central Italy, 1^{st}-2^{nd} century AD - Scorrano et al. 2014), and Velia and Herculaneum (Central and Southern Italy, 1^{st}-2^{nd} century AD - Craig et al. 2009; Martyn et al. 2018). When compared with these contexts, TAV presents $\delta^{13}C$ values that are more negative, a difference that is particularly noticeable with Casal Bertone, Gabii, Isola Sacra, and Cosa. As for $\delta^{15}N$, our data closely matches the ranges of Casal Bertone, Castellaccio Europarco, Lucus Feroniae, and Velia, is higher than Cosa, and lower than St. Callixtus, Gabii, and Isola Sacra.

Comparing sex and age classes (Figure 6b, Table 5), the only (though not significant) observed trend relates to the high $\delta^{15}N$ values of male individuals when compared with females and subadults. The highest $\delta^{15}N$ value, however, is given by a young female (TAV 58).

In respect to the funerary treatments, average $\delta^{15}N$ values differ significantly between supine and prone individuals, with the latter group exhibiting a higher value (Table 6b). Given the small number of prone individuals (N=3: TAV 89, 103, and 161), and overlap between groups, these results must be interpreted with caution. When considering $\delta^{13}C$, isotopic values do not correlate with funerary treatments (e.g. prone vs. non prone, regular vs. irregular burials) (Figure 6b, Table 6). It should be noted that individuals TAV9a and 9b (a male and a female respectively) were subsequently deposited in the same grave, as demonstrated by the position of the remains of TAV9b, which were shifted toward the eastern edge of the grave when the burial was reopened for the deposition of individual 9a. As such, the original position of the earlier individual is difficult to ascertain. However, based on the position and relative orientation of some of the skeletal parts (innominate bones, femora) we decided to consider this individual in this and the following analyses as a regular supine inhumation.

3.3. Isotopic analysis: $\delta^{18}O$ and $^{87}Sr/^{86}Sr$

Figures 7a and b, and Tables 3 and 4 show the $\delta^{18}O$ and $^{87}Sr/^{86}Sr$ values of our first and second dental samples. Carbonate $\delta^{18}O$ values of the first dental sample range from -6.5‰ to -3.1‰ (VPDB), $\bar{x} = -4.5 \pm 0.8‰$, whereas $\delta^{18}O$ values for the second dental sample range from -6.8‰ to -3.8‰ (VPDB), $\bar{x} = -5.0 \pm 0.9‰$. After applying the equation of Chenery et al. (2012), these values translate to a range of $\delta^{18}O$ in drinking water ($\delta^{18}O_{DW}$) for the first dental sample from -10.7‰ to -4.6‰ (VSMOW), $\bar{x} = -6.9 \pm 1.4‰$. For the second dental sample, $\delta^{18}O_{DW}$ values range from -10.1‰ to -5.7‰ (VSMOW), $\bar{x} = -7.7 \pm 1.3‰$.

$^{87}Sr/^{86}Sr$ values of the first dental series range from 0.70784 to 0.71348, $\bar{x} = 0.70938 \pm 0.00128$, and for the second dental series from 0.70744 to 0.71339, $\bar{x} = 0.70932 \pm 0.00132$ (Tables 3 and 4). The human dentine shows a range of $^{87}Sr/^{86}Sr$ values from 0.70886 to 0.70965, $\bar{x} = 0.70902 \pm 0.00024$ (N = 9, Table 3 and Figures 7a and b: red dotted line). A comparison of these values with a published range for the Po Plain in the Emilia Romagna region [0.7088-0.7095 (Emery et al. 2018b, see also Cavazzuti et al. 2019)], supports the reliability of our approach for the approximation of local $^{87}Sr/^{86}Sr$ baselines.

Values of $^{87}Sr/^{86}Sr$ in our sample are generally within both the local range and the ±3MAD range, with the exception of three clear outliers (TAV 103, prone, 109, with nails, and

58, supine). Both dental samples in burial 103 and 109, and the M1 sample in burial 58 are characterized by a nonlocal signature. Interestingly, both TAV 109 and TAV 58 show a marked isotopic shift between the first and second dental samples, with Sr values decreasing from M1 to M3 and PM2 respectively.

Compared with $^{87}Sr/^{86}Sr$, our samples are characterized by a higher variability of $\delta^{18}O$. The only clear outlier is TAV 109, with M1 characterized by an isotopic ratio more negative than the rest of the population and well outside the ±3MAD range. When considering M3, however, this individual fits in the isotopic range of the sample. It should be noted that the ±3MAD range for $\delta^{18}O$ is in our case extremely large, and possibly too conservative for the estimation of isotopic outliers. The percentage of nonlocals would indeed dramatically rise if considering $\delta^{18}O$ data from modern precipitation as a reference for local values (from -7‰ to -8‰). As already mentioned, this strategy is however prone to various biases and likely to overestimate the frequency of nonlocals in a sample (Lightfoot and O'Connell 2016). A possible compromise is to preliminarily consider those with values falling within, but on the limit of the ±3MAD range for $\delta^{18}O$ as nonlocals. For the first dental series, these would include TAV 9a, TAV 9b, TAV 10 (supine), and TAV 103 (prone). For the second dental series, the individuals would be TAV 109 (with nails), TAV 103 (prone), and TAV 58 (supine) (Figures 7a and b).

No statistically significant differences were found between males and females, or between adults and subadults with respect to $\delta^{18}O$. With respect to $^{87}Sr/^{86}Sr$, males have significantly higher values for both dental series (although within the local range), while no statistically significant difference separates adults from subadults (Tables 5a and 5b). No statistically significant differences were found between regular and irregular burials, or between supine and prone inhumations for both $\delta^{18}O$ and $^{87}Sr/^{86}Sr$ (Tables 6a and 6b).

4. Discussion

4.1 Osteological and archaeological features

Before addressing our starting hypotheses, we discuss the unusual features described for TAV 76, 109, and 244. Although any interpretation of TAV 76 must be considered tentative due to its extreme fragmentation, several features allow the exclusion of an unlikely suite of scenarios. The apparent lack of reactive response of the preserved bones and the anatomical distribution of the nails tend to rule out some form of either torture or execution, e.g. crucifixion. Similarly, a link between the nails and some type of wooden funerary structure is not supported by the clusters of nails found on specific anatomical positions and, especially, by the perpendicular position of these objects on the right forearm. These considerations leave the possibility of an action performed on the corpse. The presence of soft tissues, in particular, would have allowed the observed preservation of the anatomical connections which would have otherwise been subjected to dislocation and shifting due to the applied force.

In the case of TAV 109, the features of the cranial lesion tend to rule out an intervention on dry bone. This is particularly suggested by the presence of the bevelling on the endocranial surface (see Methods section), which is consistent with a penetration of the nail in the cranium around the time of death (and possibly causing the death of the individual). On the other hand, the faint extension of the endocranial bevelling suggests an event taking place when the bone was not particularly plastic, therefore sometime after death.

The features of the lesion on the innominate of TAV 244 are rather consistent with an intervention on a bone that is already poor in collagen and relatively brittle. This, together with the further insertion in the cavity of a *balsamarium*, suggests an event that took place when the corpse was at least partially skeletonized, possibly when the grave was disturbed in antiquity (see above). Regarding the meaning of these actions, any interpretation is hampered by the lack of references to similar practices in classic sources, or of any similar finding in other archaeological contexts. Similarly puzzling is the possible connection between this treatment and the prone position of the individual, the cultural meaning of which is still unclear.

Prone burials have been linked to necrophobic beliefs (Harman et al. 1981; Schleifring 1999; Wilke 1931) as well as to magico-ritual behaviours, forms of “overkill”, executions, and, in a broad sense, marginalization processes (Reynolds 2009; Taylor 2008). As for the use of nails, skeletons (or skeletal parts) transfixed by nails are sporadically reported for antiquity and mostly associated with forms of tortures or executions (Aufderheide and Rodriguez-Martin 1998: 38; Charlier 2008). The deposition of nails in Roman funerary contexts, on the other hand, is well-known, and usually interpreted as an apotropaic practice stemming from the magico-ritual features associated with these objects (Bellucci 1919; De Filippis Cappai 1997; Maioli 2010).

More importantly, no clear information is available about the real meaning of prone burials or transfixion of corpses during antiquity, most of their current interpretation being based on either later sources or ethnological parallels (Milella et al. 2015). It is therefore possible that these (admittedly quite different) practices were motivated by a heterogeneous suite of reasons and cultural traditions. Note also that in our case, the actual meaning of the nails is further obscured by the possibility of their use on a living individual. For TAV 76 this seems unlikely given the amount and distribution of these objects, but cannot be ultimately ascertained due to the fragmentation and degradation of the remains. Conversely, the cranial lesion of TAV 109 is consistent with a peri mortem event. Whether this caused the death of the individual or happened on a corpse (as the slight endocranial bevelling seems to suggest) is unclear, however. The presence of other iron nails in the burial space of TAV 109 is, similarly, of difficult interpretation (as already mentioned their morphology and position tend to exclude the use of a coffin – see above). We can discard their collocation sometime after the burial of the individual as improbable, given the absence of post depositional disturbance of the skeletal remains, as well as of any sign pointing to a reopening of the grave. This suggests a deposition of these objects contextually to the inhumation of the individual. It is also worth noticing that the size and shape of these nails largely overlap with those of the one transfixing the cranium. This, together with the position of these objects (toward the head and left shoulder) may suggest a link between the transfixion of the cranium and the presence of these nails.

4.2. Correlation between diet and funerary treatment

Our first hypothesis postulates a correlation between the diet of an individual during life and the type of its funerary treatment.

The tightly clustered $\delta^{13}C$ values in our sample point to a diet dominated by C_3 plants (e.g. wheat) with no indication of C_4 plant impact (Ambrose et al. 2003; Bender 1971; Cerling 1984; Griffiths 1992; Peterson and Fry 1987). This heavy reliance on C_3 plants agrees with the results of other studies of Imperial Rome from Central and Southern Italy (Killgrove and Tykot 2013, 2018; Martyn et al. 2018; Prowse et al. 2004; Rutgers et al. 2009; Scorrano et al. 2014; Tafuri et al. 2018). On the other hand, when compared with the other Italian Imperial samples, the more negative $\delta^{13}C$ values of the individuals from Bologna may be the by-product of various factors, including: a more consistent and regular contribution of C_3 plants to their diets, local differences in the exploitation of marine resources and of animal and plants from dense- vs. open environments, as well as regional differences in temperature and humidity (Van Klinken et al. 2000)

$\delta^{15}N$ values at TAV are rather widely spread out, and not substantially deviating from those of other Imperial samples, overall suggesting a variable access to animal proteins among these individuals (Katzenberg 2007; Schoeninger and DeNiro 1984). The Roman diet was probably quite heterogeneous, including a variable proportion of cereals, olives, wine, terrestrial meat, legumes, fish, and millet (Killgrove and Tykot 2013). At Bologna, millet – a C_4 plant – can be excluded (see above) but the presence of freshwater fish in the diet is suggested by the relatively high $\delta^{15}N$ values showed by some individuals. Applying to our data the linear model of Cook et al. (2001), which is based on $\delta^{15}N$ endpoints of 8‰ and 17‰ for, respectively, a completely terrestrial and completely aquatic diet, would result in a contribution of freshwater fish to diet ranging from a minimum of 0% to a maximum of 37%, with an average of 13.2%. Even considering the limits of these estimates (Rutgers et al. 2009; Van Strydonck et al. 2009), it is very likely that the diet at *Bononia* included a minor although variable amount of freshwater fish.

Previous isotopic analyses show evidence for considerable dietary heterogeneity across the Empire according to sex or age (Craig et al. 2009; Dupras et al. 2001; Keenleyside et al. 2006; Keenleyside et al. 2009; Killgrove and Tykot 2013; Prowse et al. 2005; Tafuri et al. 2018). In our case, $\delta^{13}C$ and $\delta^{15}N$ values largely overlap between males and females and between adults and subadults, therefore suggesting a lack of sex- or age-related differences in access to food sources. This result may help to interpret the relatively broad range of $\delta^{15}N$. One possibility is indeed that the observed isotopic variability may be the by-product of social differences (domestic vs. agricultural slaves vs. citizen – see Killgrove and Tykot 2013), with lower-status individuals having less access to animal proteins. A further possibility to consider is that the observed isotopic values may in part be the result of different dietary customs related to a nonlocal origin. In particular, this hypothesis may explain the results for TAV 103, which is characterized by both a relatively high $\delta^{15}N$ value and a strontium value suggesting a nonlocal origin (see below).

Similarly, TAV 58, the individual with the highest $\delta^{15}N$ value, is characterized by a strontium signature of the first molar consistent with a childhood spent elsewhere.

The relatively high $\delta^{15}N$ values of the prone burials TAV 89, 103, and 161 suggest a differential access to protein sources for these individuals, with a higher component of meat, dairy foods, or aquatic resources (Katzenberg 2007; Schoeninger and DeNiro 1984). While it is tempting to link such dietary features to the specific deposition of these individuals, one must stress the small size of our sample, which may bias the observed patterns and resulting interpretation, and the fact that the individual presenting the highest $\delta^{15}N$ value, a supine inhumation of a female, is not characterized by irregular features, with the possible exception of its N-S orientation.

When considering other funerary variables, the lack of clear patterns in either carbon or nitrogen values is relatively surprising, especially given the hypothesized presence in the analysed population of a certain degree of social stratification (see above). It is possible, however, that social variability at TAV, if present, was only loosely reflected by the funerary treatment, and/or that the scale of our analysis (i.e. the type of variables used in this study) obscure nuanced differences between each inhumation.

To qualify our considerations, however, it is important to point out that it is suggested that conditions of nutritional stress influence stable isotope ratios in body tissues (Beaumont et al. 2013; Crowder et al. 2019; D'Ortenzio et al. 2015; Fuller et al. 2004, 2005; Hobson 1993; Mekota et al. 2006; Reitsema 2013; Reitsema and Holder 2018; Walter et al. 2018). Elevated $\delta^{15}N$ and depleted $\delta^{13}C$ values may result from tissue catabolism or macronutrient scrambling in situation of low protein intake. Even if the individuals from irregular burials do not show paleopathological features distinguishing them from the rest of the sample (see above), the possible effect of metabolic imbalances, malnutrition, and possibly sickness need to be taken into account when considering the isotopic variability at TAV, the high $\delta^{15}N$ characterizing some of the individuals, and the possible social meaning of these patterns.

4.3. Correlation between geographic origin and funerary treatment

Our second hypothesis is the correlation between the geographic origin of an individual and its funerary treatment.

$\delta^{18}O$ and $^{87}Sr/^{86}Sr$ data indicate that the majority of the individuals are locals, with at least three individuals (20% of the analysed sample) being possible nonlocals (two of them with irregular features). This percentage would rise to 40% (6/15) if one would apply a less conservative approach and consider also the individuals occupying the limits of the ±3MAD $\delta^{18}O$ range as nonlocals (see above). Considering the likelihood of an overestimation of nonlocals in the second case, these frequencies do not exceedingly deviate from those calculated in previous isotopic studies of Roman samples from across the Empire. Nonlocals form 34.5% - 4% of the analysed individuals at Rome (Killgrove 2010b; Killgrove and Montgomery 2016), 9% at Vagnari (Southern Italy - Emery et al 2017; Prowse 2016), 23% in Portus Romae (Central Italy - Prowse et al. 2007), 30% in both Saintes (Western France - Stark 2017) and Neuburg/Donau (Southern Germany - Schweissing and Grupe 2003), with higher (40%) frequencies observed in York, Catterick, Gloucester, and Lankhills (Eckardt et al. 2010), and Roman London (42%-20% - Redfern et al. 2017; Shaw et al. 2016). Overall this suggests that patterns of mobility during the first centuries AD did not strongly differ across the Italian peninsula and Gaul, while confirming Britain as an area characterized by intense migrations/movements. It is worth noticing that this scenario is likely to be biased by the military nature (or closeness to military installations) of both Neuburg/Donau and, especially, of the majority of the British sites (see also Redfern et al. 2018). As a consequence, frequency estimates of nonlocals would reflect in these cases the presence of military personnel from various regions of the Empire. Moreover, given the relatively late datation of the British samples, their comparison with continental populations is only partially suitable, and should be approached in any case with caution. Note also that frequencies of nonlocals are influenced by the sampling strategies followed in each study. With some exceptions (Prowse et al. 2007; Schweissing and Grupe 2003; Stark 2017) the cited works analysed one tooth per individual, therefore focusing on a specific chronological windows. Also, all these studies (like ours) are based on bulk isotopic values, which represent (imperfect) averages of the within-tooth isotopic variation (see Reade et al. 2015). All these factors are likely to produce underestimates of the actual amount of nonlocals in a skeletal population.

About the higher $^{87}Sr/^{86}Sr$ values of males when compared with females, one should notice that the median of both sexes is in any case in the local range. As such, one cannot interpret their isotopic variance in terms of different geographic origin; rather, it is likely that the observed contrast in $^{87}Sr/^{86}Sr$ values is a by-product of the small sample size, the possible imprecision of bulk isotopic averages (see above), and the result of environmental factors influencing strontium ratios in the diet of an individual (Montgomery 2010).

An individual-based comparison of strontium isotopic data between dental samples provides a diachronic perspective to our reconstruction (note that the same changes in oxygen are not discussed here given the possible bias of breastfeeding (Roberts et al. 1988; Wright and Schwarcz 1998).

TAV 58 is characterized by markedly contrasting strontium isotopic values between M1 and M3, suggesting that this individual moved to the area of Bologna only after the completion of about 3 years of life but before early youth. Conversely, the slight differences in isotopic values between the dental samples of TAV 103 and 109 point to a childhood or early adolescence spent elsewhere.

The application of isotopic analysis in archaeology helps in distinguishing between "local" and "nonlocal"; it is very rare, however, to determine potential geographic origins. Hence, the actual geographic origin of the individuals in our study is difficult to infer from these data, especially due to isotopic convergence, i.e. different geographic areas sharing similar isotopic ranges.

In terms of long- versus short-distance mobility, one needs first to consider that migration across relatively far regions was not uncommon in the Roman Empire (e.g. from North Africa, the Near East, Gaul to the Italian peninsula). On the other hand, given the relative likelihood that short-distance movements were at least relatively more frequent on a regional level (cf. Haley 1991; Pearce 2012; Ravenstein 1885, 1889, Wierschowski 1995), the following discussion will focus on the Italian peninsula. Some tentative hypotheses can be advanced on the basis of a combined analysis of both strontium and oxygen isotope ratios. In particular, in the following discussion we will refer to the isotopic maps published by Giustini and colleagues (2016), and Emery and colleagues (2018b), and the work of Killgrove and Montgomery (2016).

TAV 103 is characterized by a combination of elevated strontium and oxygen values when compared with those of Bologna, pointing to a possible origin in a location featuring older geology and relatively dry climate. Possible locations include the North-West of Central Italy, or one of the islands in the Tyrrhenian Sea (Emery et al. 2018b; Giustini et al. 2016). A similar origin is also suggested by the strontium and oxygen isotope ratios of TAV 58 (M1). In this case, one must be aware of the possible bias introduced by breastfeeding on the oxygen isotopic value of the first molar, however (Roberts et al. 1988; Wright and Schwarcz 1998). The low strontium and oxygen values of TAV 109 are consistent with a geographic location with both a basalt/limestone substrate and a cool and wet climate, e.g. the Central Apennines. Finally, some hypothesis can also be formulated regarding the origin of the three individuals interpreted as possible migrants on the basis of their relatively "extreme" $\delta^{18}O$ values (TAV 9a, 9b, and 10). In the case of TAV 9a and 10, one can postulate their origin in a location featuring a slightly wetter climate than the area of Bologna, although sharing a similar $^{87}Sr/^{86}Sr$ range, like some areas of the Northern Apennines. In the case of TAV 9b, hypothesizing a possible place of origin is more difficult. When compared with the rest of the individuals, the markedly less negative $\delta^{18}O$ values of both M1 and M3, and the $^{87}Sr/^{86}Sr$ value overlapping with the estimated local range suggest a location featuring a markedly drier climate, such as the Western coast of the Italian peninsula or, possibly, other locations such as Southern Spain, Northern Africa, or the Western Mediterranean coast. This result is interesting, as would suggest that burial nine includes two individuals coming from different geographic locations.

From a funerary point of view, 3 out of 5 irregular burials present local isotopic values, whereas 1 out of 3 nonlocal individuals (3 out of 6 if considering also TAV 9a, 9b, and TAV 10) do not present irregular features. This result militates against a straightforward association between geographic origin and funerary treatment. Note that two possible nonlocals (TAV 9a, and, especially, TAV 9b) were subsequently deposited in the same burial. However, in this case, this specific funerary treatment, which in any case cannot be considered irregular, was more likely related to familiar/social relationships between the two individuals rather than to their geographic origin (which was, in any case, different).

These results are interesting both in terms of the social perception of foreigners during the first centuries AD, and in terms of the cultural attitudes of the latter in their new residence place. The lack of a clear correlation between irregular funerary treatment and geographic origin fits with similar results from previous analyses (Eckardt et al. 2009, 2012; Killgrove 2010a: 300), therefore further suggesting the presence of a broad range of factors justifying an alternative mortuary treatment. Also, our results further support the lack of a clear association between alternative funerary practices and patterns of social ostracism and/or ethnic differentiation

(Crerar 2016; Pearce 2012). On an individual level, it is of course possible that the different origin of TAV103 and 109 was somehow linked to the reasons justifying their specific funerary treatment. However, our preliminary results show that, at least at *Bononia*, this was probably not a general pattern.

During the last decade several bioarchaeological studies have explored the social correlates of mobility in the Roman Empire (Eckardt 2010; Eckardt et al. 2009, 2010, 2014; Killgrove 2010a), especially regarding the possible retention among migrants of cultural ties with their geographic origins vs. patterns of cultural integration. At TAV, cultural integration is suggested by the fact that nonlocals align with the rest of the sample in terms of grave goods and grave implements (besides the already mentioned cases of irregular treatment). This inference must be considered with caution, however, given our (necessarily) imprecise estimates of the geographic origin (and cultural distance from the population of Bononia) of these individuals, and the partial ability of archaeological data to depict the actual complexities and various facets of a funerary ritual (Trinkaus 1984).

5. Conclusion

In the presented work, we analysed a set of Roman inhumations from Bologna (Northern Italy, 1st-4th c. AD) and tested for the possible correlation between irregular funerary treatment, diet, and mobility. Results show no clear association between these variables, suggesting that funerary variability, at least in the analysed context, was not a direct representation of vertical social differences or ethnic/cultural affiliation, but was rather shaped by a variety of heterogeneous factors. This study, the first to jointly explore funerary and isotope (strontium, oxygen, carbon, nitrogen) data in a Northern Italian Roman context, demonstrates the usefulness of extending this type of analyses to areas of the Roman Empire still relatively unexplored.

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Figure legends:

Figure 1. Location of the TAV necropolis.

Figure 2. TAV 76 (young adult, unidentified sex): a) Burial upon excavation; b) Close-up with the iron nails associated to the skeleton highlighted by stars; c) Image of the proximal nail transfixing the right forearm. Bar = 4 cm. Photos by C. Cavallari, by courtesy of Soprintendenza Archeologia, belle arti e paesaggio per la città metropolitana di Bologna e le province di Modena, Reggio Emilia e Ferrara (SABAP-BO).

Figure 3. TAV 109 (young-mature female): a) Burial upon excavation. Stars highlight the iron nails. Photo by C. Cavallari, by courtesy of Soprintendenza Archeologia, belle arti e paesaggio per la città metropolitana di Bologna e le province di Modena, Reggio Emilia e Ferrara (SABAP-BO); b) Close-up of the skull in laboratory with the iron nail still *in situ*; c) Superior view of the cranium after restoration. Note the elongated lesion produced by the nail (arrow). d) Endocranial view of the same lesion. Note the slight bevelling along the posterior edge (arrow). All bars= 4 cm.

Figure 4. TAV 244 (young female): a) Burial upon excavation; b) Close-up of the pelvic area showing the vessel inserted in the left innominate bone (arrow). Photos by C. Cavallari, by courtesy of Soprintendenza Archeologia, belle arti e paesaggio per la città metropolitana di Bologna e le province di Modena, Reggio Emilia e Ferrara (SABAP-BO); c-d) medial and lateral views of the lesion on the left innominate.

Figure 5. Examples of prone burials: a) TAV 89 (young female, prone); b) TAV 161 (young male, prone). Photos by C. Cavallari, by courtesy of Soprintendenza Archeologia, belle arti e paesaggio per la città metropolitana di Bologna e le province di Modena, Reggio Emilia e Ferrara (SABAP-BO).

Figure 6. $\delta^{13}C$ and $\delta^{15}N$ values: a) isotopic values of the TAV samples compared with the means and ranges of human and faunal samples from other Italian Roman sites; b) isotopic values of the TAV samples showing sex, age, and position of each individual.

Figure 7. $\delta^{18}O_{DW}$ and $^{87}Sr/^{86}Sr$ values: a) first dental sample; b) second dental sample. Dashed lines: ±3 median deviation from the median (MAD); red dotted line: $^{87}Sr/^{86}Sr$ range of dentine

samples. $\delta^{18}O_{DW}$ (vs. SMOW) values are obtained applying the equation of Chenery (2012: $\delta^{18}O_{DW}$= 1.590 x δ^{18}Oc - 48.634) to carbonate δ^{18}O values (VPDB).

Tables

Table 1. Archaeological features of the individuals for this study. Irregular burials are highlighted in bold. F: female; M: male; n.a.: not assigned; GG: presence of grave goods; SkDist: presence of anthropic disturbance of the remains; Orientation: position of the head.

ID	Sex	Age (yrs)	Date	Irregular	Position	GG	Type	SkDist	Orientation
TAV 76	**n.a.**	**20-34**	**1st c. AD**	**Yes[a]**	**supine**	**yes**	**Simple pit**	**Yes**	**EW**
TAV 89	**F**	**20-34**	**1st c. AD**	**Yes[b]**	**prone**	**yes**	**Coffin (wood)**	**No**	**NS**
TAV 103	**M**	**35-49**	**1st c. AD**	**Yes[b]**	**prone**	**yes**	**Simple pit**	**No**	**W-NW/SE**
TAV 109	**F**	**20-49**	**1st-2nd c. AD**	**Yes[a]**	**supine**	**yes**	**Pit covered**	**Yes**	**W-NW/SE**
TAV 161	**M**	**20-34**	**1st c. AD**	**Yes[b]**	**prone**	**yes**	**Pit covered**	**No**	**EW**
TAV 244	**F**	**20-34**	**1st-4th c. AD**	**Yes[b,c]**	**prone**	**yes**	**Coffin (bricks)**	**Yes**	**EW**
TAV 6	M	≥50	1st c. AD	No	supine	yes	Cappuccina	No	NS
TAV 9a	M	≥50	3rd-4th c. AD	No	supine	yes	Pit covered	No	EW
TAV 9b	F	20-34	3rd-4th c. AD	No	supine	yes	Pit covered	Yes	EW
TAV 10	n.a.	6+/-2	1st c. AD	No	supine	yes	Pit covered	No	EW
TAV 12	n.a.	8+/-2	1st c. AD	No	supine	no	Pit covered	No	EW
TAV 14	n.a.	9+/-2	1st c. AD	No	supine	yes	Coffin (bricks)	No	EW
TAV 23	F	20-34	1st c. AD	No	supine	yes	Coffin (bricks)	No	EW
TAV 30	F	20-34	1st c. AD	No	supine	yes	Coffin (bricks)	No	NS
TAV 58	F	20-34	1st c. AD	No	supine	yes	Simple pit	No	NS
TAV 224	n.a.	15+/- 3	1st c. AD	No	supine	yes	Simple pit	No	E-NE/W-SW

[a]: transfixed by nails; [b]: prone; [c]: transfixed by balsamarium

Table 2. C and N isotopic values of the individuals for this study. Irregular burials are highlighted in bold. TAV 12 and 109 yielded <1% of collagen and are not considered. No bone samples were available from TAV 244. NS: no sample available for study; E: excluded due to lack of preserved collagen.

ID	Lab ID	Sample	C/N	%C	%N	δ^{13}C‰ VPDB	δ^{15}N‰ AIR
TAV 76	**BAV 10**	**Tibia**	**3.3**	**36.9**	**13.2**	**-20.3**	**8.2**
TAV 89	**BAV 11**	**Rib**	**3.2**	**39.5**	**14.3**	**-20.5**	**9.9**
TAV 103	**BAV 12**	**Rib**	**3.2**	**37.3**	**13.6**	**-20.6**	**10.3**
TAV 109	**BAV 13**	**Rib**	**E**				
TAV 161	**BAV 14**	**Rib**	**3.3**	**37.1**	**13.4**	**-20.1**	**10.7**
TAV 244	**BAV 16**	**NS**					
TAV 6	BAV 1	Rib	3.3	37.3	13.3	-20.1	8.5
TAV 9a	BAV 2	Rib	3.2	43.2	15.6	-19.9	9.3
TAV 9b	BAV 3	Rib	3.3	35.5	12.7	-20.1	8.8
TAV 10	BAV 4	Rib	3.3	39.3	13.8	-20.0	7.8
TAV 12	BAV 5	Rib	E				
TAV 14	BAV 6	Rib	3.3	37.8	13.5	-20.5	8.3
TAV 23	BAV 7	Rib	3.3	32.4	11.4	-20.3	8.9
TAV 30	BAV 8	Rib	3.3	37.5	13.4	-20.4	7.3
TAV 58	BAV 9	Rib	3.3	38.6	13.9	-19.7	11.3
TAV 224	BAV 15	Rib	3.2	40.5	14.8	-20.4	9.3

Table 3. Sr and O isotopic values of the individuals for this study (first dental series), and dentine strontium values. Irregular burials are highlighted in bold.

NS: no sample available for study; Sample (dent): samples used for the analysis strontium in dentine; $^{87}Sr/^{86}Sr$ dent: dentine strontium values.

$\delta^{18}O$ drinking water ($_{\delta18ODW}$) (vs. SMOW) values are obtained converting the carbonate $\delta^{18}O$ values (vs. VPDB) using the equation of Chenery et al. (2012): *$\delta^{18}ODW= 1.590 \times \delta^{18}Oc - 48.634$*.

Id	Lab ID	Sample	$^{87}Sr/^{86}Sr$	±2SE	$\delta^{18}O_C$‰ VPDB	$\delta^{18}O_{DW}$‰ SMOW	Sample (dent)	$^{87}Sr/^{86}Sr$ dent	±2SE
TAV 76	**BAV 10**	**NS**							
TAV 89	**BAV 11**	**M1**	**0.70902**	**0.00002**	**-4.1**	**-6.3**			
TAV 103	**BAV 12**	**M1**	**0.71348**	**0.00001**	**-3.6**	**-5.3**	**M1**	**0.70965**	**0.00001**
TAV 109	**BAV 13**	**M1**	**0.70784**	**0.00001**	**-6.8**	**-10.7**	**M1**	**0.70886**	**0.00001**
TAV 161	**BAV 14**	**M1**	**0.70924**	**0.00001**	**-4.2**	**-6.5**	**M3**	**0.70892**	**0.00002**
TAV 244	**BAV 16**	**M1**	**0.70910**	**0.00001**	**-4.2**	**-6.4**	**M1**	**0.70897**	**0.00002**
TAV 6	BAV 1	M1	0.70898	0.00001	-5.0	-7.6	M1	0.70894	0.00002
TAV 9a	BAV 2	PM1	0.70934	0.00001	-5.4	-8.3			
TAV 9b	BAV 3	M1	0.70916	0.00001	-3.1	-4.6	M1	0.70900	0.00001
TAV 10	BAV 4	M1	0.70896	0.00001	-5.3	-8.2			
TAV 12	BAV 5	M1	0.70854	0.00001	-4.3	-6.5			
TAV 14	BAV 6	M1	0.70898	0.00002	-4.4	-6.6	M2	0.70889	0.00001
TAV 23	BAV 7	M1	0.70895	0.00002	-4.2	-6.4			
TAV 30	BAV 8	M1	0.70928	0.00001	-4.4	-6.7			
TAV 58	BAV 9	M1	0.71078	0.00002	-3.9	-5.8	M1	0.70909	0.00001
TAV 224	BAV 15	M1	0.70904	0.00001	-4.5	-6.9	M3	0.70889	0.00002

Table 4. Sr and O isotopic values of the individuals for this study (second dental series). Irregular burials are highlighted in bold. NS: no sample available for study.

$\delta^{18}O$ drinking water ($_{\delta18ODW}$) (vs. SMOW) values are obtained converting the carbonate $\delta^{18}O$ values (vs. VPDB) using the equation of Chenery et al. (2012): *$\delta^{18}ODW = 1.590 \times \delta^{18}Oc - 48.634$.*

Id	Lab ID	Sample	$^{87}Sr/^{86}Sr$	±2SE	$\delta^{18}O_{C}$‰ VPDB	$\delta^{18}O_{DW}$‰ SMOW
TAV 76	**BAV 10**	**NS**				
TAV 89	**BAV 11**	**M3**	**0.70897**	**0.00001**	**-4.7**	**-7.2**
TAV 103	**BAV 12**	**M3**	**0.71339**	**0.00001**	**-3.9**	**-5.8**
TAV 109	**BAV 13**	**PM2**	**0.70744**	**0.00001**	**-6.5**	**-10.1**
TAV 161	**BAV 14**	**M3**	**0.70884**	**0.00003**	**-5.2**	**-8.1**
TAV 244	**BAV 16**	**M3**	**0.70911**	**0.00001**	**-4.8**	**-7.4**
TAV 6	BAV 1	M2	0.70899	0.00002	-5.0	-7.7
TAV 9a	BAV 2	M3	0.70938	0.00002	-5.0	-7.7
TAV 9b	BAV 3	M3	0.70918	0.00001	-3.8	-5.7
TAV 14	BAV 6	M2	0.70898	0.00002	-5.4	-8.3
TAV 23	BAV 7	M2	0.70928	0.00002	-6.0	-9.3
TAV 30	BAV 8	M3	0.70935	0.00001	-5.1	-7.9
TAV 58	BAV 9	M3	0.70921	0.00001	-4.1	-6.2
TAV 224	BAV 15	M3	0.70907	0.00001	-5.6	-8.7

Table 5. Results of Wilcoxon test with Monte Carlo simulation (10.000 resampling) on isotopic values between a) sexes and b) age classes (adults vs. subadults). Significant differences are highlighted in bold. I= first dental series; II= second dental series. Med= Median; SE= standard error.

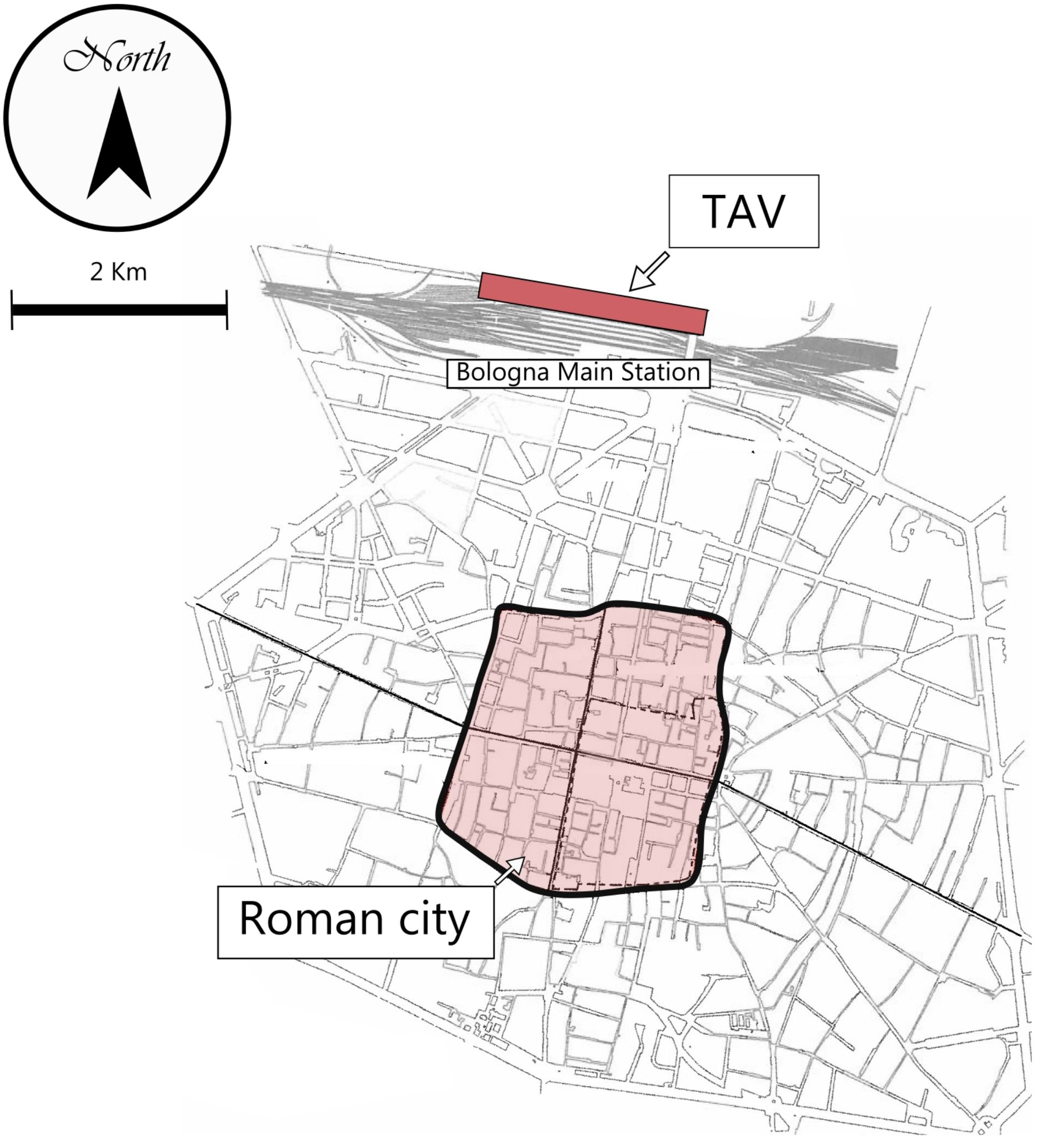
a)	Females			Males			
	N	Med	SE	N	Med	SE	p
$\delta^{15}N$	5	8.9	0.7	4	9.8	0.5	0.72
$\delta^{13}C$	5	-20.3	0.2	4	-20.1	0.1	1
$\delta^{18}O_{dw}$ (I)	7	-6.4	0.7	4	-7	0.7	0.53
$\delta^{18}O_{dw}$ (II)	7	-7.4	0.6	4	-7.7	0.5	1
$^{87}Sr/^{86}Sr$ (I)	7	0.7091	0.00033	4	0.70929	0.00108	0.01
$^{87}Sr/^{86}Sr$ (II)	7	0.70918	0.00025	4	0.70918	0.00109	0.01

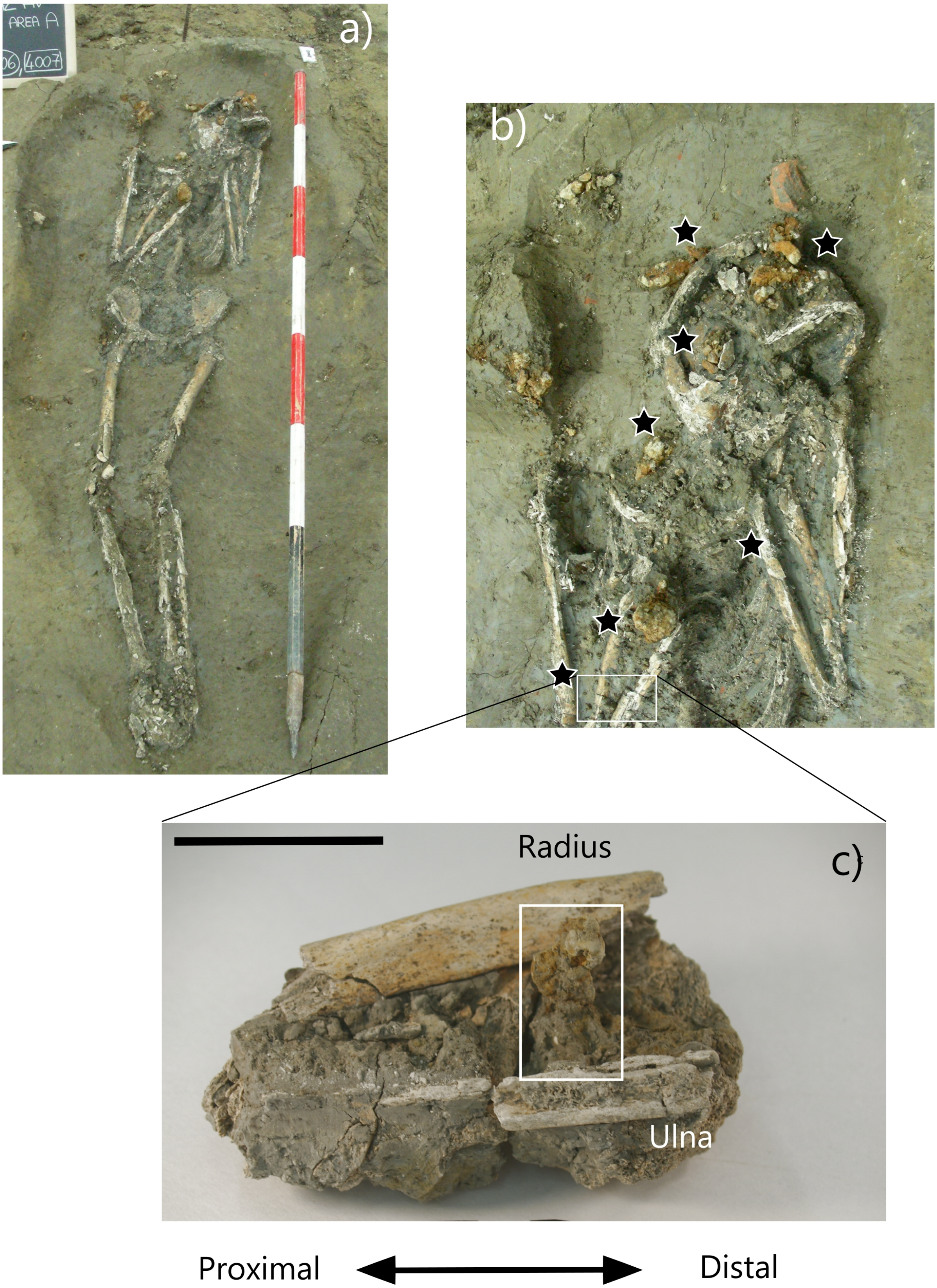
b)	Adults			Subadults			
	N	Med	SE	N	Med	SE	p
$\delta^{15}N$	10	9.1	0.4	4	8.3	0.3	0.18
$\delta^{13}C$	10	-20.2	0.1	4	-20.4	0.2	0.3
$\delta^{18}O_{dw}$ (I)	11	-6.4	0.5	4	-6.8	0.4	0.28
$\delta^{18}O_{dw}$ (II)	11	-7.7	0.4	2	-8.5	0.2	0.23
$^{87}Sr/^{86}Sr$ (I)	11	0.70916	0.00044	4	0.70897	0.00011	0.1
$^{87}Sr/^{86}Sr$ (II)	11	0.70918	0.00043	2	0.70902	0.00004	0.52

Table 6. Results of Wilcoxon test with Monte Carlo simulation (10.000 resampling) on isotopic values between funerary categories: a) regular vs. irregular burials; b) supine vs. prone inhumations. Significant differences are highlighted in bold. I= first dental series; II= second dental series. Med= Median; SE= standard error.

a)	Regular			Irregular			
	N	Median	SE	N	Median	SE	p
$\delta^{15}N$	10	8.6	0.3	4	10.1	0.6	0.2
$\delta^{13}C$	10	-20.2	0.1	4	-20.4	0.1	0.2
$\delta^{18}O_{dw}$ (I)	10	-6.6	0.4	5	-6.4	0.9	0.4
$\delta^{18}O_{dw}$ (II)	8	-7.8	0.4	5	-7.4	0.7	0.8
$^{87}Sr/^{86}Sr$ (I)	10	0.709	0.0002	5	0.7091	0.001	0.1
$^{87}Sr/^{86}Sr$ (II)	8	0.7092	5E-05	5	0.709	0.001	0.4

b)	Supine			Prone			
	N	Median	SE	N	Median	SE	p
$\delta^{15}N$	**11**	**8.5**	**0.3**	**3**	**10.3**	**0.2**	**0**
$\delta^{13}C$	11	-20.3	0.1	3	-20.5	0.1	0.2
$\delta^{18}O_{dw}$ (I)	11	-6.7	0.5	4	-6.3	0.3	0.1
$\delta^{18}O_{dw}$ (II)	9	-7.9	0.5	4	-7.3	0.5	0.3
$^{87}Sr/^{86}Sr$ (I)	11	0.709	0.0002	4	0.7092	0.0011	0.1
$^{87}Sr/^{86}Sr$ (II)	9	0.7092	0.0002	4	0.709	0.0011	0.3


North
2 Km
TAV
Bologna Main Station
Roman city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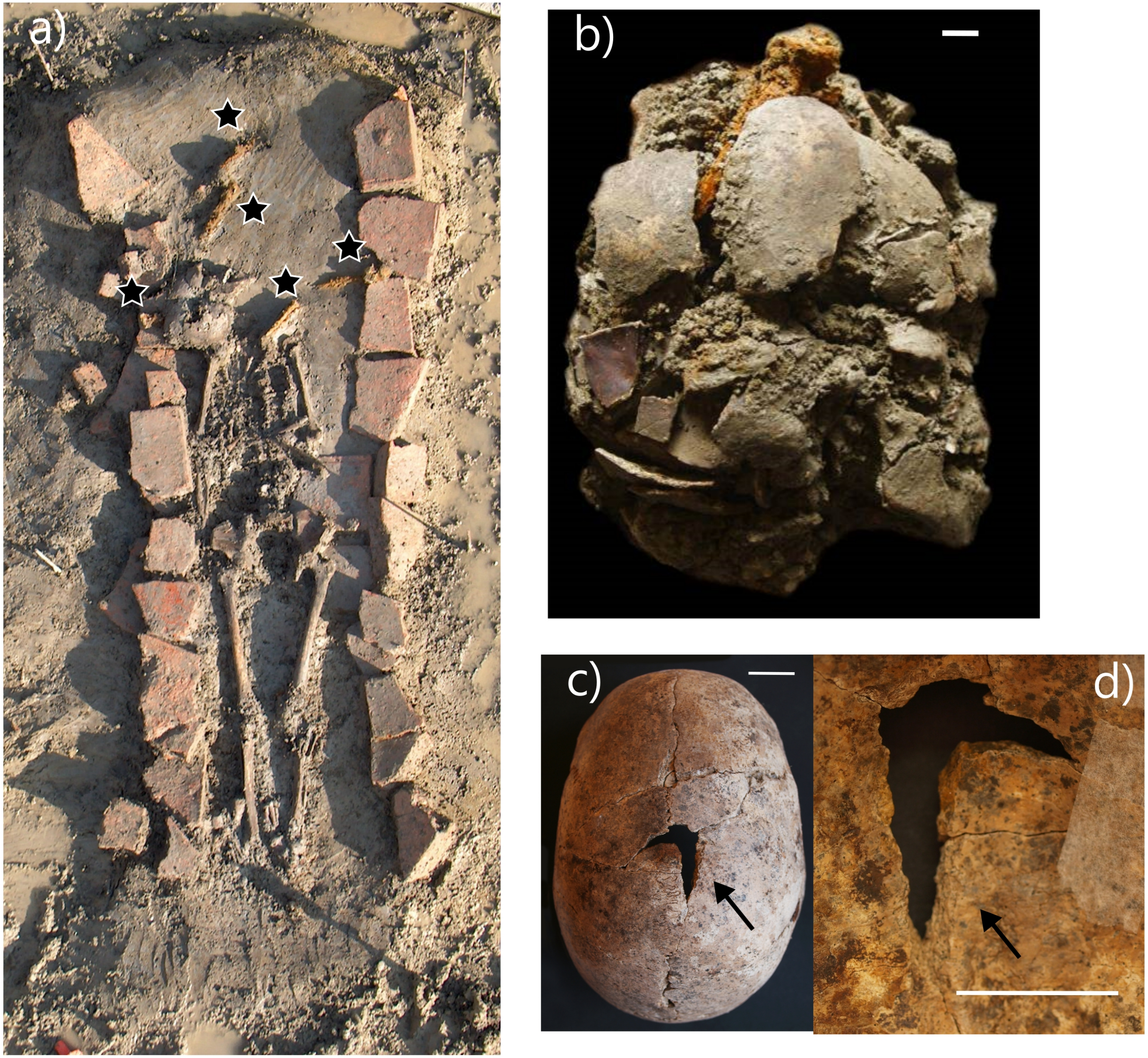
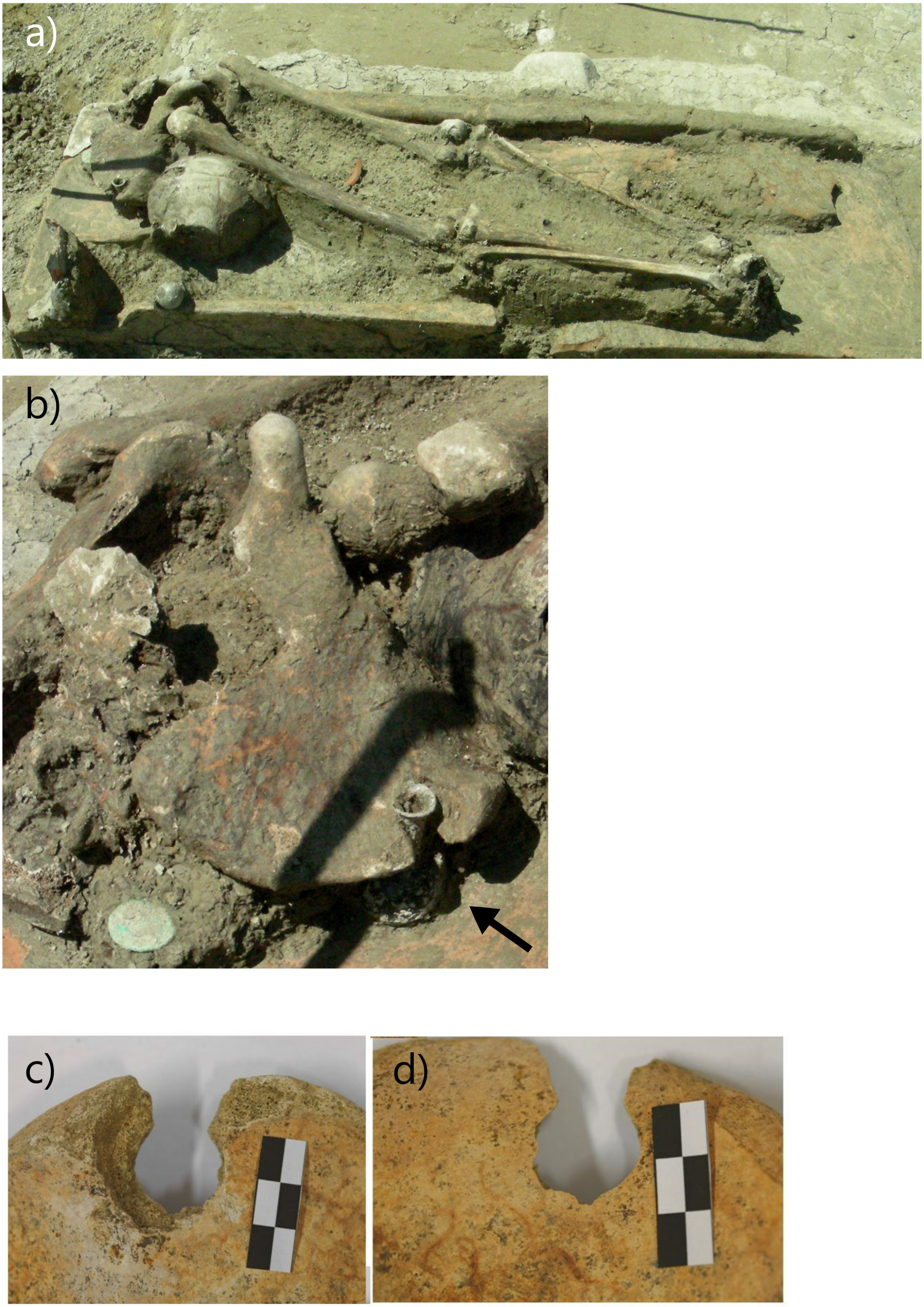
AREA A
4007
b)
Radius
c)
Ulna
Proximal
Distal


a)
b)
c)
d)


a)
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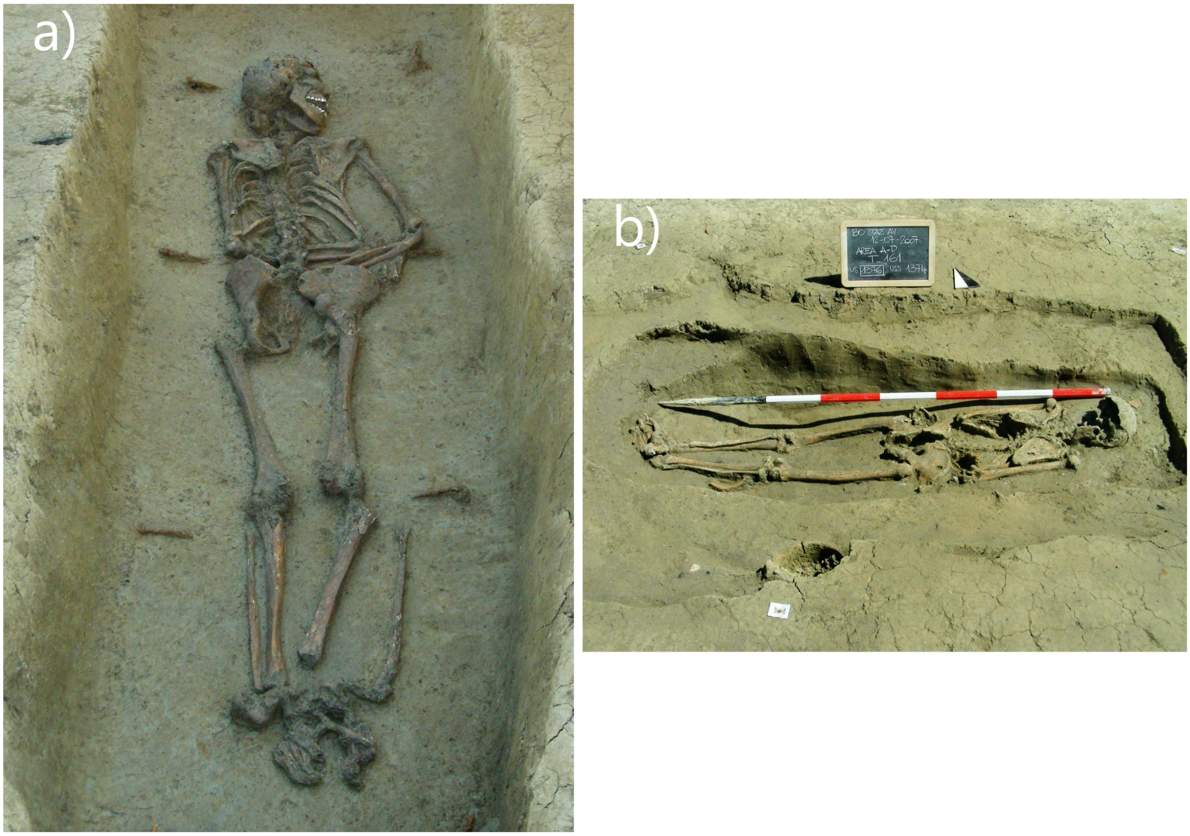
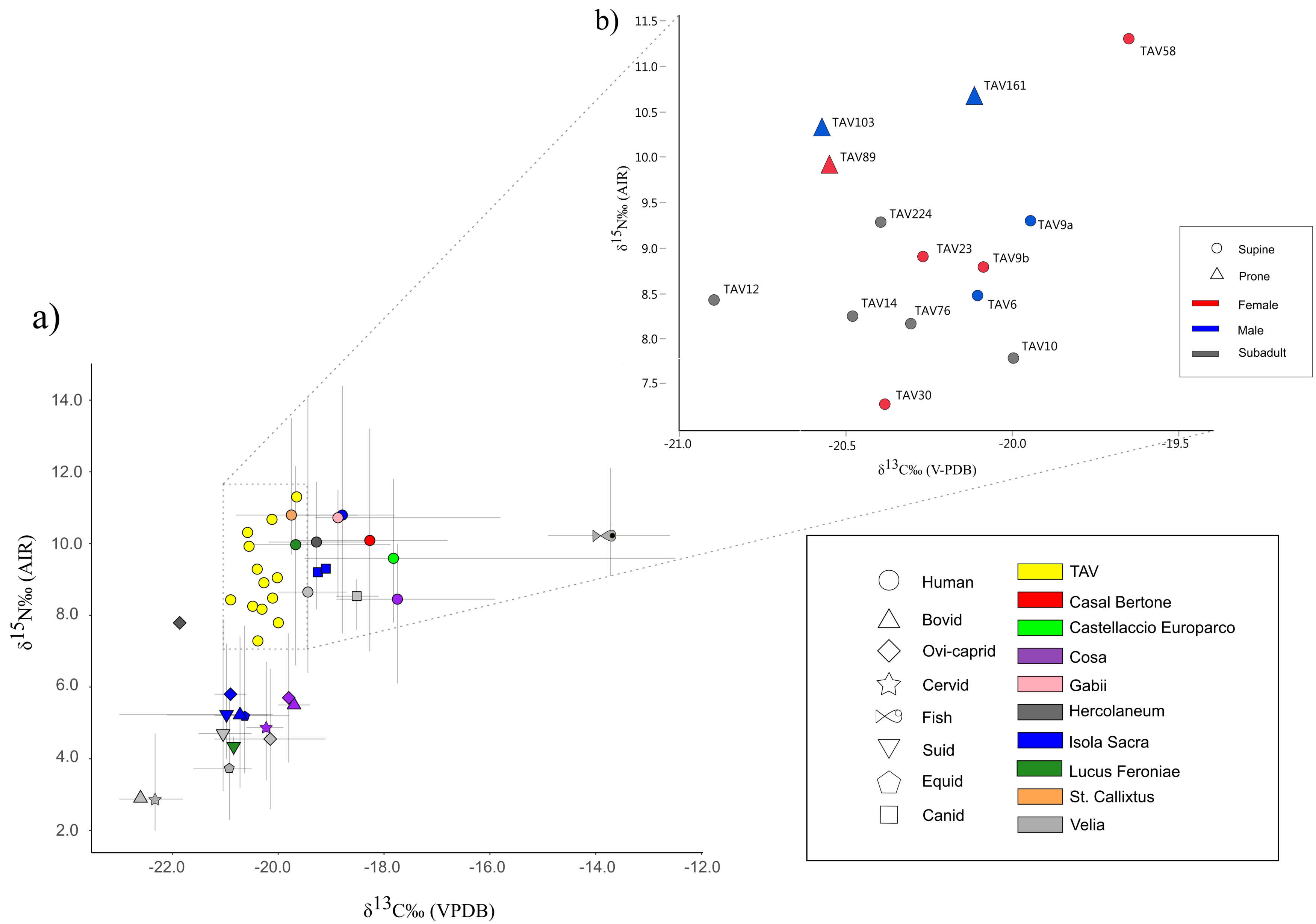
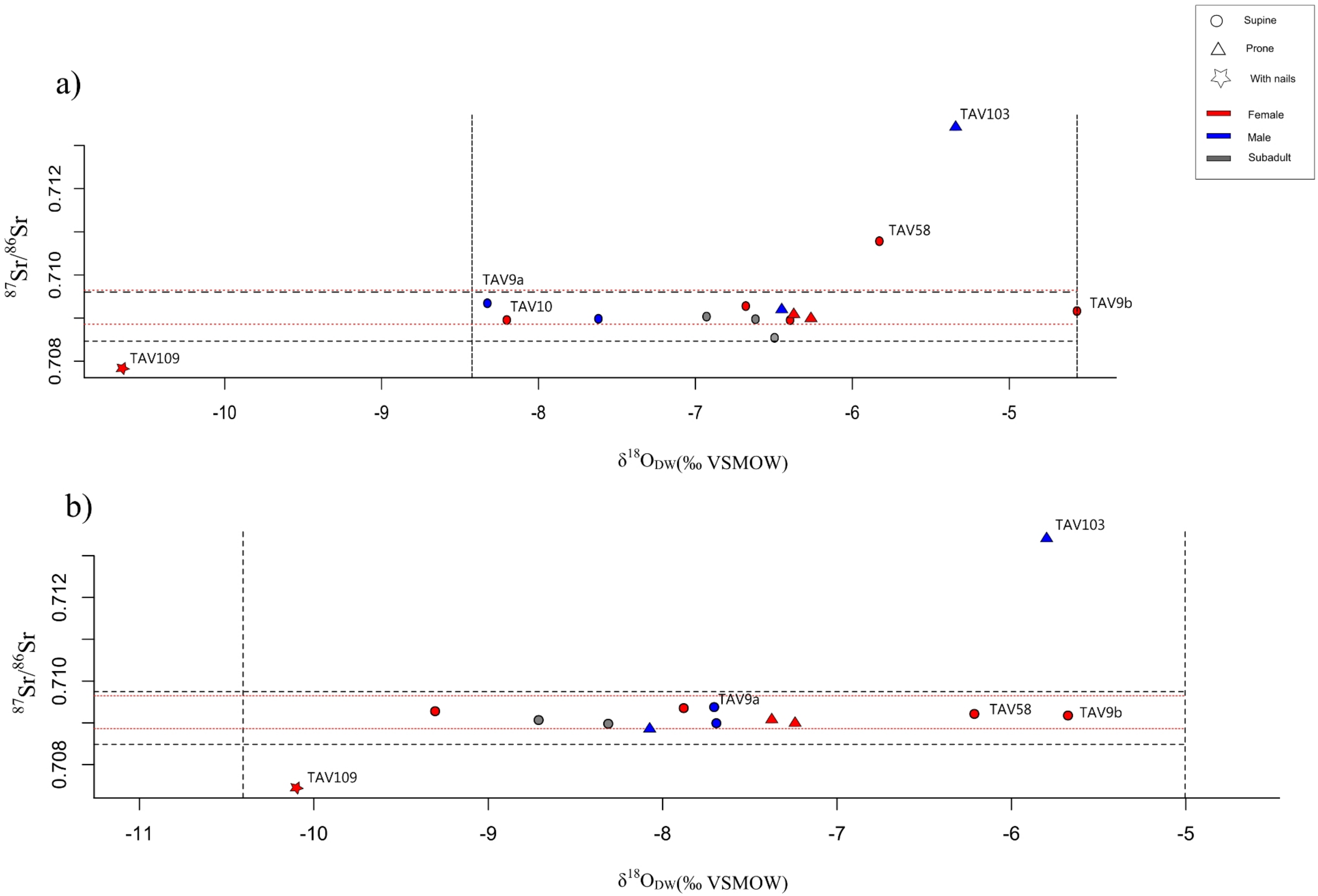
d)


a)
b)



a)
b)
δ15N‰ (AIR)
δ13C‰ (VPDB)
δ13C‰ (V-PDB)
TAV58
TAV161
TAV103
TAV89
TAV224
TAV9a
TAV23
TAV9b
TAV12
TAV14
TAV76
TAV6
TAV10
TAV30
Supine
Prone
Female
Male
Subadult
Human
Bovid
Ovi-caprid
Cervid
Fish
Suid
Equid
Canid
TAV
Casal Bertone
Castellaccio Europarco
Cosa
Gabii
Hercolaneum
Isola Sacra
Lucus Feroniae
St. Callixtus
Velia



a)
b)
Supine
Prone
With nails
Female
Male
Subadult
TAV103
TAV58
TAV9a
TAV10
TAV9b
TAV109
0.708
0.710
0.712
$^{87}Sr/^{86}Sr$
-11
-10
-9
-8
-7
-6
-5
$\delta^{18}O_{DW}$(‰ VSMOW)