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The study of commingled non-adult human remains: Insights from the 16th–18th centuries community of Roccapelago (Italy)

Carla Figus[a,*,1], Mirko Traversari[a,1], Lucia Martina Scalise[a], Gregorio Oxilia[b,a], Antonino Vazzana[a], Laura Buti[a], Rita Sorrentino[a,d], Giorgio Gruppioni[a], Stefano Benazzi[a,c]

[a] Department of Cultural Heritage, University of Bologna, via degli Ariani 1, 48121 Ravenna, Italy
[b] Department of Biology, University of Florence, Via del Proconsolo, 12, 50122 Florence, Italy
[c] Department of Human Evolution, Max Planck Institute for Evolutionary Anthropology, Deutscher Platz 6, 04103 Leipzig, Germany
[d] Department of Biological, Geological and Environmental Sciences, University of Bologna, Via Selmi 3, 40126 Bologna, Italy

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ABSTRACT

A post medieval mass grave containing hundreds of skeletons, many of which belonging to non-adults, has been discovered. A large-scale multidisciplinary study has been undertaken, thanks to the good preservation of the human remains and the availability of the parish records. This is the first study focused on the juvenile post medieval community of Roccapelago, which aims to provide new data about infant mortality and paleopathology during the 16th and 18th centuries, through the comparison of anthropological data to information available by parish records. The specimen under investigation belongs to the most ancient stratigraphic context of the crypt discovered under the floor of the church, part of an ongoing study. Standard anthropological protocols were used to assess the minimum number of individuals, age-at-death and pathologies. Results show a high mortality range between the last few weeks in utero and the first postnatal year. The comparison shows that historical records lines up with biological data, providing a unique opportunity to compare anthropological protocols for age estimation to the information registered in parish records when dealing with commingled juvenile remains.

1. Introduction

Non-adult skeletal remains can provide a large amount of data about mortality, birth, health, nutrition, growth and socio-economic development of the society they belong to (Perry, 2006; Lewis, 2007); besides, infant mortality rates are important and fundamental indicators of population health and life style. Such information may support our understanding of past societies, because non-adult skeletal samples are supposed to represent the most susceptible indicators of biological and cultural changes (Mensfort et al., 1978; Van Gerven and Armelagos, 1983; Bogin, 1988; Roth, 1992). Juveniles are complicated to study, mainly because of their small size and frailness, which accelerate taphonomic processes (Lewis and Rutty, 2003; Bello et al., 2006; Lewis, 2007). Despite the growing attention paid to juvenile remains during archaeological excavations, and the increasing number of in-depth studies (e.g. Bennike et al., 2005; Lewis and Gowland, 2007; Lewis, 2010; Burt, 2013; Duren et al., 2013; Geber, 2014), disarticulated non-adult skeletal remains recovered from mass graves are still rarely examined (Hoppa and Gruspier, 1996; L'Abbé, 2005; Tocheri et al., 2005; Baustian, 2010; Ellis, 2016; Mack et al., 2015; Haddow et al., 2016), ultimately limiting any coeval and non-coeval comparisons.

Here, we study the post-Medieval non-adult individual retrieved from the crypt of “Chiesa della Conversione di San Paolo” church in Roccapelago (Modena, Italy), a small village located ca 1095 m above sea level in the Apennines. Our aim is to provide new data on infant mortality and paleopathology in Roccapelago during the 16th and 18th centuries, highlighting the importance of non-adult skeletal remains from commingled archaeological contexts.

1.1. Historical background

Roccapelago is a small village, situated in Emilia-Romagna Region, northern Italy. The 13th–14th century fortress of the Montegarullo family, one of the most powerful families in northern Italy, was partially converted into a church in the 16th century, after the decline of the

* Corresponding author at: Department of Cultural Heritage, University of Bologna, via degli Ariani 1, 48121 Ravenna, Italy.
E-mail address: carla.figus@studio.unibo.it (C. Figus).
[1] These authors contributed equally to this work.

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Montegarullo family. Afterwards, the Roccapelago community became a genetically isolated (Cilli et al., 2015) and humble mountain parish. Their livelihood depended on agriculture, pastoralism and seasonal herding. Transhumance was a common practice (Gruppioni et al., 2010), and was confirmed by cross-checking historical information and genetic evidence, that confirmed genetic affinities with populations of Piana di Lucca, Grosseto, and Siena (Tuscany) (Cilli et al., 2015). During the 16th to the 18th centuries, the living conditions were harsh, characterized by poor hygiene and sanitary conditions. The diet was relatively rich in carbohydrates and low in proteins (Gruppioni et al., 2010). Vegetables and fruits were, probably, only available during some periods of the year, but it is known that in the Emilia region, cereals (such as sorghum), forest product such as chestnuts, and blueberries (Cazzola, 1997) were consumed.

According to historical records, the community buried the corpses in a crypt under the church's floor, from the end of 16th century to 1786, when the current cemetery was built outside the church. The underground burial chamber was no longer in use, and fell into oblivion since the first excavation in 2009, led by the archaeological firm "Ditta Barbara Vernia", under the scientific direction of the superintendence (Soprintendenza per i Beni Archeologici dell'Emilia Romagna).

A considerable number of skeletal remains was recovered. Some of these were partially mummified due to the cool, dry and ventilated climate condition in the burial chamber that led to a rapid dehydration of the corpses (Gruppioni et al., 2010; Petrella et al., 2016). The crypt was rectangular with the maximum axis oriented north-south, and was characterized by a vaulted ceiling and a rocky floor. A door, allowing access to the crypt, was walled in ancient times, probably after the earthquake of the 16th century, as evidenced by a crack on the wall above the enclosed door. Afterwards, the corpses were carefully lowered down using a trapdoor. This closed space allowed the almost total preservation of the remains. The decomposition took place in empty space and the depositions were all primary burials, (except for the burials from the most ancient layer, as explained in paragraphs 1.3. and 2.1.) (Duday, 2011), but the continuous deposition of new corpses and the decomposition itself, with the loss of volume of the bodies, caused a slight movement of the corpses, leading to disarticulation and mixing of the remains.

The complex stratification of the bodies together with their critical state of preservation required a particularly careful removal of the remains, which was conducted by hand by expert anthropologists (including one of the authors, MT).

1.2. Utilization periods

Five utilization periods have been recognized (Fig. 1). The most ancient skeletal remains, belong to the stratigraphic unit (SU) 28. The chronology of this stratum, dated to the second half of the 16th century and the first half of the 17th century (Gruppioni et al., 2010), is suggested by archaeological findings (pottery, textile, some poor grave goods). From this SU, only few bodies were recovered, completely skeletonized and poor preserved due to the weight of the upper layers. The bodies were partially buried in the natural recesses of the ground and no soft tissues nor clothes were preserved.

This layer was covered with a landfill layer 3–4 cm thick, labelled SU27. Above it, SU26 yielded fairly well-preserved skeletal remains. In this SU, the bodies were not buried, but simply deposited on each other without any ground cover. Bodies were buried with tunics, heavy socks and shrouds, as many fragments of textile can testify (Lorenzini and Schoenholzer, 2013; Traversari and Milani, 2016). They were quite well-distributed in the room area, attesting that, during this phase, the crypt was still accessible through the door. This SU were covered with a 3–4 cm thick layer of little rocky fragments (SU25), above which lay SU23, which is the most recent layer. The latter was characterized by a mound mostly made of mummified bodies, which the highest point was located directly under the trapdoor. Soon after death, the bodies were lowered through the trapdoor, suggesting that the crypt was no longer accessible from the door (Gruppioni et al., 2010). Finally, SU34 (Tomb 9) is placed on the edge of SU26 and cut it, consequently it is more recent than SU26. The lack of grave goods or textile made it impossible to date this layer more accurately. Archeologists noticed that no preferential treatment was given to children's burials, retrieved from every SU, together with the adults, even if a mention about "a grave of the angels" was found in the parish records (Traversari et al., 2016).

The large majority of the 16th–18th century Roccapelago population was buried in the crypt. A large-scale multidisciplinary investigation was undertaken to reconstruct the health status, life style, and paleodemographic profile of this post-Medieval Apennine community (Gruppioni et al., 2010; Traversari and Milani, 2011; Traversari and Milani, 2016; Traversari et al., 2016). However, a complete and thoroughly anthropological investigation for the non-adult members of this community was never published before. The skeletal assemblage from Roccapelago, in combination to the historical information from the parish records recently published by Traversari et al. (2016), provide a unique opportunity to accurately study the demography of an Italian post-medieval community. Furthermore, this comparison allows to test the accuracy of the various anthropological approaches for age estimation used in this work (Maresh, 1970; Fazekas and Kòsa, 1978;

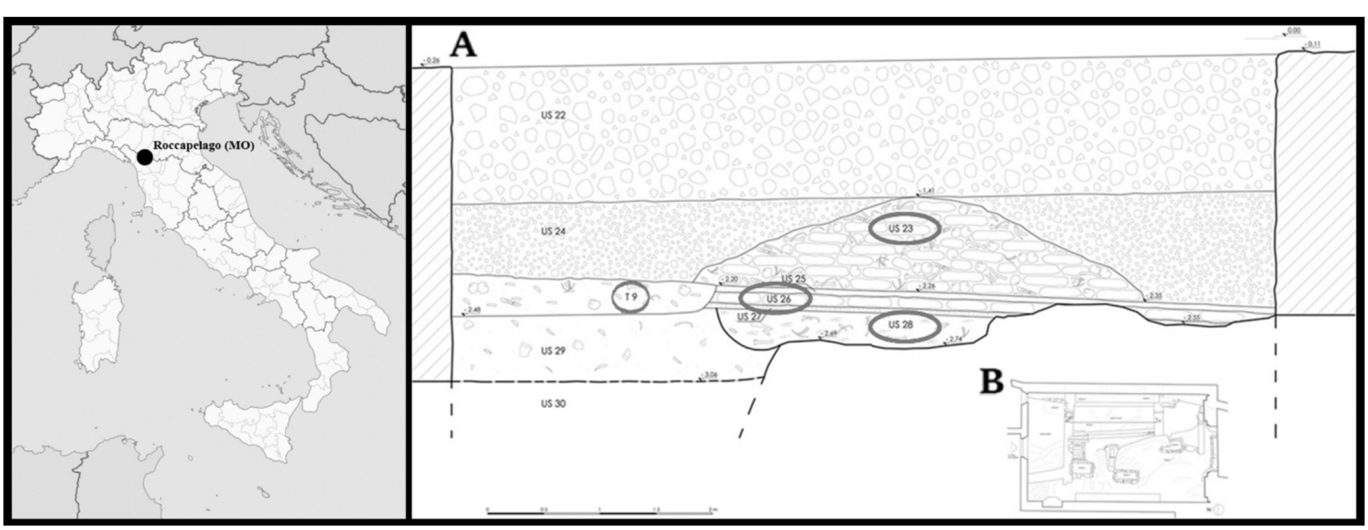

Fig. 1. A: Stratigraphic units in the crypt. The layers that yielded human remains are SU23, SU26, SU28 and Tomb 9 (T9); B: general map of the site.

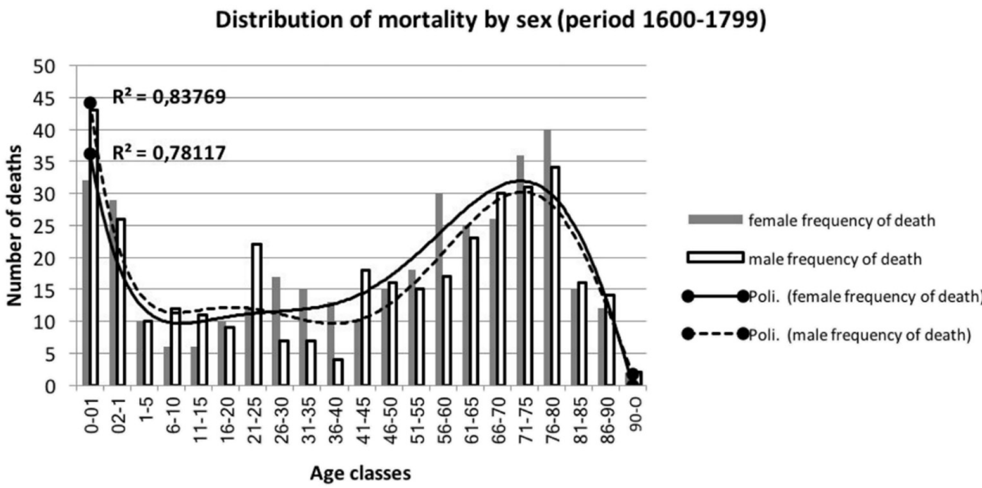

Fig. 2. The mortality profile based on the parish death records of Roccapelago (age in years).

Scheuer et al., 1980; Black and Scheuer, 1996; Schaefer and Black, 2007; Alqahtani et al., 2010).

1.3. The parish records

Parish records were recovered and digitized (i.e. Archivio Parrocchiale di Roccapelago, Libro dei Morti 1599–1738; Archivio Parrocchiale di Roccapelago, Libro dei Morti 173–1891), enabling the study of the therein information. Several priests contributed to their compilation, therefore the writing style and the type of information therein provided varies. A thoroughly study of the registers provided fundamental information about birth, pathologies and cause of death (Traversari and Milani, 2012; Traversari et al., 2016). The mortality profile extracted by these documents for the years 1600 to 1799 (Fig. 2) (Traversari et al., 2016) is rather typical, showing a rather even mortally ratio for the two sexes. About 60% of the individuals is represented by adults between 30 and 49 years old. Children have a high representativeness under the first year of age: the major peak of death is between birth and the first postnatal months, followed by a second peak between the second postnatal month and one year of age. Male mortality rate rose over the age range 21–25 years of age, while an increase in female mortality occurred between 26 and 40 years of age.

2. Materials and methods

The sample included the non-adult human remains from the most ancient layers of the crypt (i.e. SU28 and SU26). This osteological assemblage can be described as long-term usage commingled assemblage (Osterholtz et al. 2013), formed of disarticulated and commingled bony elements not attributable to specific individuals.

Generally, the survival of juvenile bones was good, since they had been recovered mostly intact and all the anatomical districts are represented, although in different proportion (Figs. S1–S2). According to McSweeney et al. (2010), smaller bones were probably less subject to fragmentation because their small size and compact shape let them to get into spaces between bigger bones. Despite the low fragmentation rates, that involved mostly cranial bones and ribs, SU28 yielded a poorly preserved and completely skeletonized sample, except for two partially mummified hands. Bones show localized cortical bone erosion, especially on the metaphyseal plate. The preservation rate slightly improved in SU26, probably due also to the larger sample. Anyhow, the bones were completely skeletonized, and only a lower limb (i.e., right tibia and fibula) was retrieved in anatomical connection due to the presence of ligamentous tissues. Fragmentation occurred especially among cranial bones, due to their frailty. The axial skeleton was subject to erosion, probably related to taphonomic processes, including rodent's teeth marks, especially on the metaphyseal plate, sometimes serious enough to prevent any metric analysis.

The anthropological analysis was carried out in the laboratory of Physical Anthropology of the University of Bologna (Ravenna Campus). First of all, a sorting out of the human bones from non-human bones (mostly from rodent) was performed. Afterwards, each bone was sorted by type and side, according to the standards proposed by Buikstra and Ubelaker (1994). Therefore, we calculated the Minimum Number of Individuals (MNI), based on the most represented element (White, 1953; Adams and Konisberg, 2004). Since the skeletal remains were not fragmented, every single specimen was considered for MNI calculation, but the bones showing various degrees of erosion were excluded from any further analysis. The number of excluded specimen is reported in the relative tables. Estimation of age at death was based on the following methods: level of epiphyseal closure and/or fusion of ossification centers (Schaefer and Black, 2007); dental development and eruption (Alqahtani et al., 2010); measurement of diaphyseal length (Maresh, 1970; Fazekas and Kòsa, 1978; Black and Scheuer, 1996; Scheuer et al., 1980). A sliding caliper was used to collect the linear measurements, which were recorded to the nearest 0.1 mm. The sample was divided into five age classes, according to Scheuer and Black (2000) after Knussmann (1988), and then adapted to our sample as follows: Class 1, preterm-perinatal under 40 weeks; Class 2, infants under 1 year of age; Class 3, infants between 1 and 5 years of age; Class 4, children between 6 and 10 years of age; Class 5, children older than 10 years of age. The presence of pathologies was evaluated through macroscopic examination with the aid of a magnifying glass. The interpretation of the pathological signs was difficult owing to the lack of association of the skeletal elements, which prevented the formulation of differential diagnose. We followed the criteria proposed by Ortner and Ericksen (1997) for the assessment of abnormal porosity.

Finally, absolute and relative frequencies (e.g., for type of bone preserved, for pathological conditions) were computed in the Analysis Toolpak of Excel (Microsoft).

3. Results

3.1. SU28

The most represented bone in SU28 is the left humerus (Table 1), which delivered a MNI of 14 non-adults. The age-at-death ranged from 35.7 weeks to 9 years. Mean age-at-death based on long bone (i.e., humerus, femur and tibia) length was between 36 and 38 weeks of gestation (Table 2, Fig. S1, Table S1), suggesting that mortality rate reached its peak in Class 1 (preterm/perinatal). The almost complete absence of teeth in the alveolar sockets made it impossible to estimate the age based on dental eruption. Moreover, the poor preservation of the bones enables us to measure and classified only two hemi-

Table 1
SU 28 - Sample divided by age and side. The percentage in bracket is related to the total number for each side.

	Class 1		Class 2		Class 3		Class 4		Not determinable		Total	
Skeletal element	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
Humerus	3(37.5%)	6 (43%)	2 (25%)						3 (37.5%)	8 (57%)	8	14
Tibia	6 (54.5)	10 (77%)	2 (18.1%)	2 (15.3%)	2 (18.1%)	1(8%)			1(9.1%)		11	13
Clavicle									10 (100%)	12 (100%)	10	12
Hemi-man[a]			1		1(25%)				3 (75%)	10 (100%)	4	10
Femur	4 (67%)	5 (55.5)	2 (33%)	2 (22.2%)		2 (22.2%)					6	9
Ulna	2(28.5%)	4 (50%)	1 (14.2%)	2 (25%)	1(14.2%)			1(12.5%)	3 (42.8%)	1(12.5%)	7	8
Hemi-max[b]				2 (40%)					2 (100%)	3 (60%)	2	5
Mandible			1 (33.33%)		1 (33.33%)				1 (33.33%)		3	

[a] Hemi-mandible.
[b] Hemi-maxilla.

mandibles and two hemi-maxillae. Only few individuals belonging to Class 4 were found, while no skeletal remains from Class 5 (> 10 years) were retrieved in this SU.

3.2. SU28 – health condition

Pathological analysis revealed the presence endocranial porotic lesions on the 14.28% of the frontal bones (n = 2/14 on the right side of the frontal bone) and abnormal porosity on the 14.28% of the right pars squama and 15.38% on the left side (1/7 and 2/13, respectively). Only one pars squama within the perinatal sample was affected by porotic lesions. Some porosity signs were found on five upper alveolar bones, with a frequency of 40% (3/5 on the left side), belonging to individuals older than 1 year of age. No fractures, signs of sub-periosteal new bone formation, nor other pathological markers were observed on the post-cranial skeleton. Dental pathologies could not be assessed, due to the lack of in situ teeth.

3.3. SU26

The most represented bone in SU26 was the left humerus, which delivered a MNI of 62 non-adults (Table 3). The age-at-death ranged from 36.4 weeks to 9 years. Based on long bone length (Table S2), most of the individuals fall in Class 1 with a mean age-at-death between 36 and 38 weeks of gestation (Table 4). The clavicles represent an exception, suggesting a slight increase in the mortality rate between 0 and 6 postnatal months (Class 2) (Table S3). The mandibles showed a similar pattern to the long bones, indicating a higher mortality rate during the last weeks of gestation, with a mean age-at-death between 35 and 38 weeks of gestation (Table 5), followed by a slightly lower mortality rate during the first postnatal year. Class 3 is represented by few mandibles and maxillae (Table S4), with an estimated age at death of about 1.8 and 2 years, respectively. Only two specimens (both humerus) belonging to two individuals of Class 4 were found.

3.4. SU26 – health condition

A list of cranial pathologies observed in the SU26 non-adult individuals is summarized in Table 6. Several cranial bone fragments belonging to Classes 1 and 2 showed abnormal porosity, mostly on the *pars petrosa*. Abnormal porosity of the ectocranial surface and orbit roof were observed on the frontal bone of the perinatal/neonatal sample. The frequency of abnormal cranial porosity is 19% on the right elements (n = 6/31), 15% on the left elements (n = 5/34) and 20% on undetermined specimens (n = 2/10). Abnormal porosity on the orbital roof is recorded on 29% of right orbital bone (n = 9/31), 38% on left ones (n = 13/34) and 10% of undetermined remains (n = 1/10). Abnormal porosity was observed on the great wings of the sphenoid bone and on the hard palate and extended beyond the alveolus of the maxilla. On the great wings, porosity was present on 30% of right elements (n = 4/13) and 45% of left ones (n = 9/20) in Class 1, while in Class 3 was observed on 14% of right elements (n = 1/7), and on 25% of left elements (n = 2/8). With regard to the maxilla, the first two classes are interested, with a frequency of 66% on right side (n = 2/3) and of 44% on the left side (n = 4/9) (Class 1) and 50% on right side (n = 10/20) and 31% on left side (n = 4/13) in Class 2 (Fig. 4). No relevant pathological markers were recorded on mandible and postcranial skeleton, except for few cases of sub-periosteal new bone formation (n = 20/445) and porosity (n = 9/445). Furthermore, two cases of greenstick fracture on as many ribs, and two cases of probable post-traumatic myositis on a fragmented rib and on a right clavicle (the latter aged 30–32 prenatal weeks) were observed (Fig. 5). Unfortunately, only few teeth were present in the alveolar socket, showing no dental pathologies. Finally, a case of pink teeth in a Class 2 maxilla was registered.

Table 2
SU 28 – Mean age-at-death according to humerus, femur, and tibia.

	Humerus (left)			Femur (left)			Tibia (left)		
Classes	Observed	Analyzed	Age (range)	Observed	Analyzed	Age (range)	Observed	Analyzed	Age (range)
1[a]	35	26	36.89 (31.92–40.58)	29	22	35.68 (30.29–39.76)	25	15	37.9 (33.72–40.57)
2[b]	16	14	4.69 (1–9)	22	11	3.75 (1.5–9)	15	13	3.94 (1 – 12)
3[c]	8	7	2.35 (1–4)	2	2	1.5 (1–2)	7	3	3.5 (1.5–5)
4[c]	2	2	9 (8–10)				1	1	7 (−)
Not determinable							7	0	–

[a] Weeks.
[b] Months.
[c] Years.

Table 3
SU 26 - Sample divided by age and side. The percentage in bracket is related to the total number for each side.

	Class 1		Class 2		Class 3		Class 4		Not determinable		Total	
Skeletal elements	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
Humerus	25 (62.5%)	36 (58%)	13 (32.5%)	16 (26%)	2 (5%)	8(13%)		2 (3%)			40	62
Tibia	30 (50%)	25 (45%)	22 (37%)	15 (27%)	3 (5%)	7 (13%)		7 (13%)	5 (8%)	1 (2%)	60	55
Femur	36 (63%)	29 (55%)	15 (26%)	22 (41%)	6 (11%)	2 (4%)					57	53
Clavicle	14 (28%)	10 (16%)	15 (30%)	17 (27%)	13(26%)	10(16%)	2(4%)	2 (3%)	6 (12%)	7(11%)	50	46
Ulna	22 (48%)	25 (51%)	18 (39%)	15 (31%)	6 (13%)	9 (18%)					46	49
Half mandible	12 (44%)	19 (48%)	11 (40%)	13 (33%)	–	–	–	–	4 (14.8%)	7 (17%)	27	39
Half maxilla		9 (36%)	19 (82.6%)	13 (52%)	2(8.7%)	3 (12%)			2 (8.7%)		23	25
Mandible			4 (22%)		9 (50%)				5 (28%)		18	

4. Discussion

4.1. Age-at-death

Commingled human remains represent a challenge for the study of paleodemography, especially if belonging to non-adults and if not uniformly well preserved. We performed a comprehensive study of the osteological record from SU26 and SU28, and we discussed the most represented and informative skeletal elements. SU28 and SU26 represented slightly different time periods. Nonetheless, the mortality curved overlapped despite the different sample sizes, showing no changes throughout time. High mortality rates at birth, and during the first year of life were found (Fig. 3). This is not unexpected, considering that women and perinates faced a high risk of death during pregnancy or delivery (Pfeiffer et al., 2014). Risk of death during delivery was one of the major causes of death, especially between primiparae. The necessity of maintaining high birth rates could have led to an early weaning age at Roccapelago. This is suggested by our high estimated average of childbirth per mother (see paragraph 1.1). A direct calculation of the fertility rate was not possible, but we estimated the average of childbirth per mother, that was 6, with a peak of 13 deliveries per mother (personal communication). Wells et al. (2012) suggested that mortality rates of young female adult increased with the onset of a sedentary life and relative dependence on agricultural food production, while some scholars (Stulp et al., 2011; Rozenholc et al., 2007) noticed an increase in risks during deliveries in women of short stature in modern medical contexts. In this respect, biological data show that the average height of women in SU28 was about 152 cm, with an increase of 5 cm in SU26 (personal communication). The results obtained by an assessment of dental development (formation and eruption) were consistent with those based on diaphyseal length. Both highlighted a high rate of perinatal mortality (Class 1), followed by a second increase during the first few postnatal months (Class 2). It is well-known that dental development is less influenced by environmental insults (e.g., maternal malnutrition, preterm deliveries, twin births, pathologies and potential illness or malnutrition during first postnatal months) than skeletal growth (Smith, 1991). In fact, dental development is believed to be more reliable for age estimate since it is determined by genetic background (Rallison, 1986; Bennike et al., 2005). Nevertheless, our findings showed a rather consistent mortality profile. The study of parish records supports our results, as it shows a high percentage of deaths between birth and the first postnatal month, and throughout the first year of life (Class 1 and Class 2, respectively), with an increased frequency around the 5th postnatal month compatible to the early weaning period. The priests did not indicate when a preterm birth occurred, making it impossible to know at which week of gestation the stillbirth occurred. Interestingly, the parish records report the expression "emergency baptism" next to some birth entries, suggesting that complications arose during the delivery. This notation appears in 3.02% of the total births in Roccapelago, but its frequency increased when twin births are considered (13.73%). Notably, none of the twins who received the emergency sacrament survived (Traversari et al., 2016).

Table 5
SU26: Mean age-at-death according to the mandible.

		Observed	Analyzed	Age (range)
Right	Class 1[a]	12	12	38.75 (34–40)
	Class 2[b]	11	4	5.4 (4.5–10.5)
	Not determinable	4	0	
Left	Class 1[a]	19	19	35.8 (28–40)
	Class 2[b]	13	5	6.3 (4.5–7.5)
	Not determinable	6	0	
Mandible Class 2[b]		9	4	9 (7.5–10.5)
Mandible Class 3[c]		11	9	1.6 (1.5–2.5)

[a] Weeks.
[b] Months.
[c] Years.

4.2. Health status

The occurrence of stressors, probably related to a poor diet, anemia, pathogens agents, inflammatory conditions, infections, gastrointestinal disease (Ortner, 2003; Lewis, 2007; Halcrow et al., 2014) is suggested

Table 4
SU 26 – Mean age at death according to humerus, femur and tibia.

Classes	Humerus (left)			Femur (right)			Tibia (right)		
	Observed	Analyzed	Age (range)	Observed	Analyzed	Age (range)	Observed	Analyzed	Age (range)
1[a]	35	26	36.89 (31.92–40.58)	36	28	36.38 (30.63–39.85)	30	21	36.89 (30.15–40)
2[b]	16	14	4.69 (1–9)	15	9	2.69 (1–4.5)	22	17	3.95 (1.5–12)
3[c]	8	7	2.35 (1–4)	6	5	1.15 (1–1.25)	3	3	1.08 (1–1.25)
4[c]	2	2	9 (8–10)						
Not determinable							6	0	–

[a] Weeks.
[b] Months.
[c] Years.

Table 6
SU 26 - Cranial pathologies.

Skeletal element	Classes of age	Porosity		Infections			Porosity of the pars petrosa (temporal bone)		Porosity of the pars squama (temporal bone)		*Cribra cranii*			*Cribra orbitalia*		
		Right (%)	Left (%)	Right (%)	Left (%)	n.d.[a] (%)	Right (%)	Left (%)	Right (%)	Left (%)	Right (%)	Left (%)	n.d.[a] (%)	Right (%)	Left (%)	n.d.[a] (%)
Sphenoid bone	I	4/13 (30)	9/20 (45)													
	II															
	III	1/7 (14)	2/8 (25)													
Temporal bone	I						4/9 (44)	3/16 (19)	3/7 (43)	2/10 (20)						
	II															
	III			1/10 (10)	1/10 (10)			1/1 (100)								
	IV			3/14 (21)												
	n.d.					2/7 (28)										
Frontal bone	Perinates/neonates										6/31 (19)	5/34 (15)	2/10 (20)	9/31 (29)	13/34 (38)	1/10 (10)
Maxilla	I	2/3	4/9													
	II	9/20 (45)	4/9 (44)													
	III	0/2	0/3													

[a] n.d.: not determinable.

by the presence of diagnostic markers. The presence of abnormal porosity may be caused by some pathological conditions as osteomyelitis, rickets, scurvy, anemia, hypertrophic (pulmonary) osteoarthropathy, and leukemia as well as a consequence of traumatic events (Brickley and Ives, 2008; Weston, 2008). Abnormal porosity was identified on several cranial bones, in particular on the greater wing of the sphenoid, the orbit roof, the hard palate and the posterior maxilla, on the ectocranial surface of parietal and frontal bones (Figs. 4, 5).

The presence of abnormal porosity on the cranial vault could be correlated to anemia, scurvy and malnutrition (Lewis and Roberts, 1997), but it might also develop after delivery trauma (Schultz et al., 2007) or chronic hemorrhages with damage of vein vessels, parasitic presence or pathogens agents. Lewis (2007) claimed that endocranial lesions could be correlated to infections or hemorrhages owing to vitamin C deficiency or child abuse. Porotic hyperostosis is therefore to regard as a non-specific stress indicators.

Wapler et al. (2004) showed that the microscopic appearance of *Cribra orbitalia* may be due to several pathological causes. This condition is thought to be indicative of malnutrition and/or pathogen load resulting in iron-deficiency anemia during childhood (Mensforth et al., 1978, Weinberg, 1992; Stuart-Macadam, 1991), metabolic disorders, infectious disease, parasitism and weanling diarrhea (Ortner, 2003). Porosity in combination with small, speculated new bone formation in the orbital roofs and on the ectocranial surfaces could also be linked to rickets (Ortner and Mays, 1998).

Pars squama and *pars petrosa* show signs of hyper vascularization or hemorrhages compatible with vitamin or iron deficiencies (Ortner, 2003).

The presence of abnormal porosity on the hard palate and posterior maxilla could be linked, according to Ortner et al. (1999), to chronic hemorrhage of the greater palatine artery's vessels during swallowing in individuals with a vitamin C deficiency.

The presence of abnormal porosity and disorganized new bone on the great wings of the sphenoid bones strongly indicates the presence of scurvy. The impossibility to analyze the pattern of bilateralism of the lesions required more cautious (Brickley and Ives, 2006), even if some scholars suggested that this kind of lesion is pathognomonic for scurvy (Ortner, 1999; Ortner et al., 2001; Ortner and Ericksen, 1997; Ortner, 2003).

With regard to the appendicular skeleton, the woven appearance of the growing bone does not allow to establish with accuracy the presence of porosity and/or sub-periosteal new bone formation, possibly leading to an underestimation of some pathological conditions in non-adults. These lesions were thought to be a non-specific indicator of stress, but their etiology is much more complex (Weston, 2008; DeWitte, 2014). In fact, sub-periosteal new bone formation occurs in response to local or systemic infection o inflammation in association with multiple factors such as localized trauma, hypertrophic (pulmonary) osteoarthropathy, treponemal disease, cutaneous ulcers, scurvy, rickets, and tuberculosis (Ortner, 2003; Weston, 2008).

Unfortunately, due to the commingled nature of our sample, it is not possible to determine a number of individual affected by any pathological condition.

4.3. Differential diagnosis

Commingled assemblages inevitably undermine paleopathological considerations, as it is not possible to combine evidences from different skeletal districts, ultimately affecting any conclusive differential diagnosis.

None of the pathological changes described in paragraph 4.3 is strongly diagnostic. However, the consideration of the recurrence on specific locations of the lesions listed above is pivotal in the identification of, at least, the most likely pathological condition (Brickley and Ives, 2008). According to Ortner (1999), the pattern of skeletal changes throughout the skeleton should help to distinguish scurvy from anemia

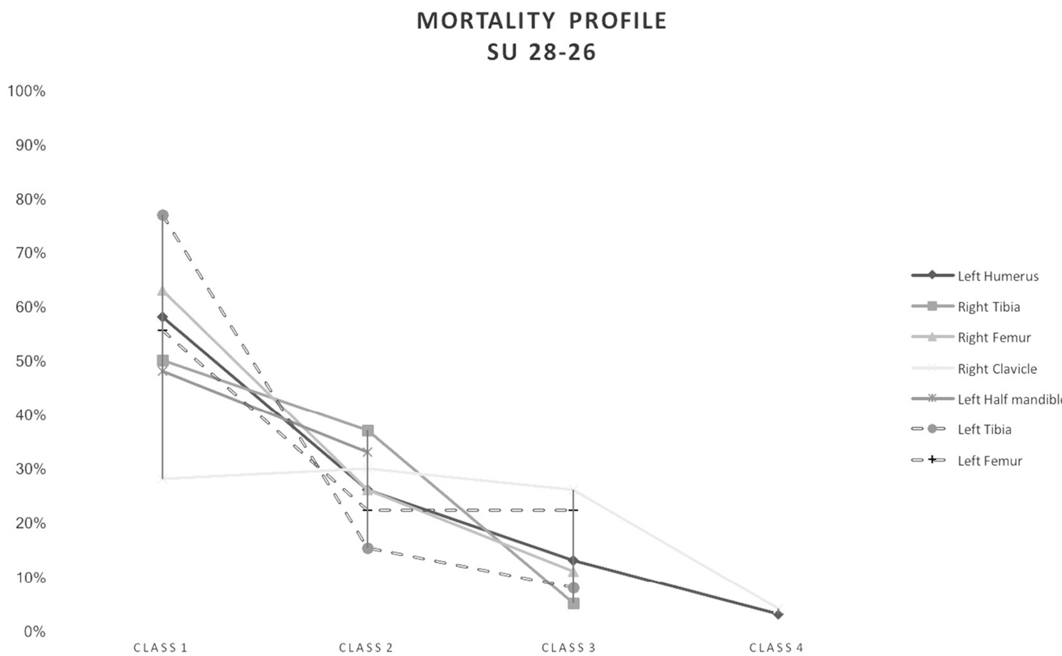

Fig. 3. Mortality profile. The dashed lines represented SU28.

Fig. 4. Porosity on the hard palate of two different maxillae (SU26).

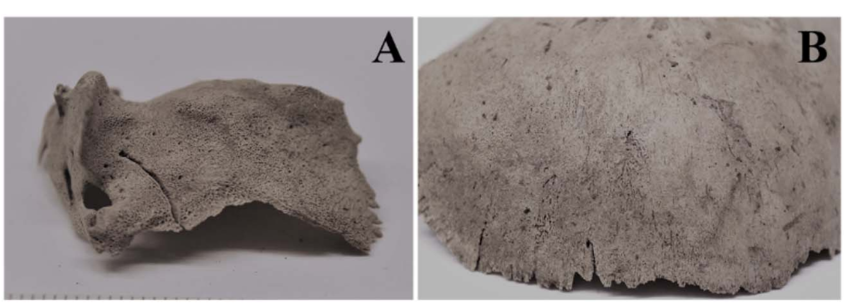

Fig. 5. A: porosity on the great wing of the sphenoid (SU26). B: Porosity on a parietal bone (SU26).

and rickets, although the co-morbidity should always be considered. The abnormal porosity observed in our sample showed holes that penetrate the cortex on specific bony elements consistent with vascular response to scorbutic chronic bleeding (Ortner et al., 2001). Moreover, given the presence of porosity on the greater wing of the sphenoid (Ortner, 1999), we suggest that the abnormal porosity found in our sample could be suggestive of scurvy.

Scurvy is a pathological condition caused by the lack of Vitamin C that leads to defective collagen and osteoid synthesis resulting in skeletal growth retardation and hemorrhagic phenomena (Aufderheide et al., 1998; Ortner, 2003; Brickley and Ives, 2006; Ortner et al., 1999). This defect is the cause of the main issues linked to scurvy (e.g. defective osteoid formation and lack of small blood vessel wall integrity, resulting in hemorrhagic phenomena).

According to Lewis (2007), scurvy occurs commonly between 6 months and two years of age. This age range is consistent with a relatively vulnerable period that includes weaning timing and consequent stress, resulting from dietary deficiency of the mother (Brickley and Ives, 2008; Halcrow et al., 2014). The time of the onset of this pathology is also indicative of the harsh living condition of the population of Roccapelago, as skeletal changes consistent with scurvy were observed also in the perinatal sample, suggesting that poor maternal diet

Fig. 6. Rib fracture (SU26).

was lacking the required nutrients necessary for the infant's health (Brickley and Ives, 2008). Interestingly, according to Cazzola (1997), fresh fruit and vegetables were scarce at Roccapelago, ultimately supporting the hypothesis of scurvy. Vitamin C is present in marine fish, vegetables, and fruit (Aufderheide et al., 1998). A poor and restricted diet could be the consequence of an inhospitable climate: studies conducted by Brown and Ortner (2011) highlighted that cold environments and mountain areas could make really tough finding fruits and vegetables during some months of the year. Roccapelago was an isolated village on the Apennines, and its location probably allowed only and insufficient amount of fresh fruit and vegetables during at least some months of the year. The greatest difficulties were probably the altitude of the site (1.095 m a.s.l.) and the scarcity of plains available for cultivation: the winters were rather long (from September to March) and in summer, the narrow Pelago valley limited exposure to sunlight.

The recognition of metabolic conditions is of importance also to gather additional information about the socio-economic status of the community under study (Ortner et al., 2001). The relative poverty in addition to the postnatal mothering could have played a fundamental role in the health of the infant community of Roccapelago. In their study of four cemeteries sites of varying socio-economic status in England (18th–19th C), Newman and Gowland (2017) highlighted how the social status influenced the prenatal and postnatal care strategies, leading to higher rates of infant morbidity in the lower status sample, while infant mortality was high in all the studied samples.

4.4. Trauma

Trauma is also variously present in the sample. The two greenstick fractures of the ribs showed bone reaction, suggesting that the child (or the children) survived the trauma at least for a couple of weeks, but he/she did not survive until the bone completed its healing process (Fig. 6). This kind of fracture is frequently observed in non-adults and may be caused by a number of insults, such as physical abuse (Lewis, 2010), bony dysplasia, metabolic disease, cancer, osteopenia (Glass et al., 2002; Lewis, 2007, 2010), violent cough or other infections associated with malnutrition (Kopcsanyi et al., 1969), or simply a blow in the injured area. Unfortunately, the ribs could not be reassembled to any individual, making it impossible to establish if the child (or the children) showing the fracture on the ribs was (or were) affected by other pathologies. However, based on the observation of the two ribs, which showed no other pathological signs but the fracture, any other pathological condition could be ruled out.

4.5. Dental health

A case of maxillary pink teeth is represented in Roccapelago. This phenomenon is related to ante-mortem trauma or unspecific postmortem taphonomic processes reported in subjects who have died rapidly and whose bodies have been buried in a wet or moist environment, particularly if in a prone position (Campobasso, et al., 2006, Borrman et al., 2014). This position, in fact, could facilitate the draining of postmortem fluids in the dental area. Few deaths by drowning or resulting from trauma are recorded in the parish records, but only adults were involved. Given the position of the corpses in the crypt and the dripping of postmortem fluids towards the lower layers, the taphonomic hypothesis is highly likely.

4.6. Concluding remarks

In the last few years, several studies analyzed non-adult human remains, focusing on mortality profiles, pathologies, growth patterns, weaning traditions (Tocheri et al., 2005; Lewis, 2010; Lewis and Gowland, 2007; Sparks et al., 2013; Burt, 2013; Duren et al., 2013; Geber, 2014;). Few researches investigate commingled non-adult remains (Hoppa and Gruspier, 1996; L'Abbé et al., 2005; Tocheri et al., 2005; Baustian, 2010; Flensborg et al., 2015; Ellis, 2016; Mack et al., 2015; Haddow et al., 2016) highlighting the importance that they have in paleodemographic studies. In fact, adult skeleton is unable to reflect the biocultural changes as fast as juvenile skeleton does, since it encounters a more rapid bone growth and remodeling than the mature bones, leading to a swifter environmental reflection (Ellis, 2016).

Spatially and chronologically analogous samples to Roccapelago are not available for a direct comparison of the results, however the mortality profile in Roccapelago SU28 and 26 matches the expected profile. Our results suggest that the infant age distribution does not differ from the natural expected mortality distribution (e.g. peak at birth and during the first year of life). The work of Baustian (2010) follows similar criteria to estimate age-at-death because of the nature of commingled remains of the sample and show a similar mortality profile to Roccapelago, with high mortality rates between birth and 1 year.

In conclusion, the present study on the non-adult individuals retrieved from the 16th–18th century funerary crypt of Roccapelago allowed reaching three main goals. In particular, we confirmed the paleodemographic profile as reported in the parish record, which is in accordance with the expected mortality distribution. The high rate of perinatal mortality is related to the harsh living condition of this poor mountain community. Moreover, we reported on the general health conditions of the non-adult population of Roccapelago, highlighting the pivotal role of the identification of skeletal changes in the process of identification of the most likely diagnosis when dealing with non-adult commingled remains. Unfortunately, even if we suggested the presence of scurvy in the non-adult community, the nature of commingled assemblages limits any attempt of a thorough differential diagnose. The presence of other pathological condition as anemia cannot be completely excluded. Furthermore, the anthropological approaches for age estimation were benchmarked against the information retrieved in the parish records.

Since this study is a part of an ongoing project that aims to study the entire community of Roccapelago, further investigations will interest the human remains from other layers, in order to draw attention to the living and health conditions of this community through the ages.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.jasrep.2017.06.023.

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