Growth problems in a skeletal sample of children from the foundling wheel of Santa Casa da Misericórdia, Faro, Portugal (16th-19th centuries)

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Running title: Growth in a skeletal sample of abandoned children

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Abstract

In 2006, an excavation in *Santa Casa da Misericórdia de Faro*, Portugal, revealed a cemetery (16th-19th centuries) with several phases of use, one of which with 51 sub-adult individuals that had been delivered to the institution through the foundling wheel. From the 46 individuals for whom it was possible to estimate age-at-death, more than 80% were under two years. Skeletal samples from individuals of these ages are not commonly found in the archaeological record. The Faro's sample is also unique in the sense that it is the first time to be able to study an osteological assemblage from abandoned children. Considering the assertion that dental development is buffered against environmental insults in comparison to skeletal development, and that discrepancies between dental and skeletal age estimations are suggestive of growth delay, this study aims to investigate if the immature individuals of this institution were exposed to severe environmental restrictions. Skeletal age was estimated according to long bone lengths and epiphyseal fusion. Dental age was calculated on the basis of dental development, namely dental calcification and the sequence of formation and eruption of teeth. Furthermore, a palaeopathological analysis of the sample was conducted. The age estimates obtained by the ossification and fusion of different skeletal elements resulted in too wide intervals and were therefore excluded from subsequent analysis. The age estimates obtained by the dental methods were consistent (100%). By contrast, the estimates obtained by osteometric and dental methods showed some disagreement (osteometric vs. dental calcification: 63.6%; osteometric vs. sequence of formation and eruption of teeth: 80.0%), the osteometric providing younger ages. Regarding the paleopathology, the high frequency of porotic lesions (60.8%) and new bone deposition (37.3%), especially in the individuals previously identified as small for their age, make evident the difficulties experienced by these individuals during their short life.

Introduction

In 2006, an archaeological survey done before the rehabilitation of the building of *Santa Casa da Misericórdia de Faro*, Faro, Portugal, brought to light a necropolis (16th-19th centuries) with several phases of use: 1) three adult burials with an East-West orientation, with their heads to the West (in accordance to the Christian belief in the resurrection of the soul); 2) one large ossuary and 27 adult burials of both sexes and different ages-at-death; and 3) 51 inhumations of sub-adults, chronologically more recent, mainly with a South-North orientation. There were, however, a few exceptions in the orientation of the position of the skeletons: six individuals were buried with a Southwest-Northeast orientation, one with a Southeast-Northwest orientation and one with a North-South orientation. None of the sub-adults had a typical Christian orientation (Corga and Ferreira, 2010). Although this third phase is stratigraphically more recent than the previous, the absence of archaeological material prevented us to reduce the time span of these burials. Unfortunately, it was not possible to perform a radiocarbon analysis of the remains that would allow for a more precise chronology of the series. *Santa Casa da Misericórdia* is a group of confraternities based on religious values and with charitable purposes. In those days, these were divided into fourteen works of mercy (Sá, 1997; Abreu, 2000), two of which were the burial of the dead and the care of abandoned children (Sá, 1997; Araújo, 2000; Fonte, 2004). The abandoned new-borns were received at the institution through the foundling wheel – *Roda dos Expostos*. This device, built into the wall with a revolving door, was designed with the aim to abandon ("expose" in the language of the time) new-borns, maintaining the anonymity of the abandoner (Fonte, 2004; Dias, 2008; Leandro, 2011). The anonymity was in fact a crucial issue because in several instances, these women were young and single mothers from all socioeconomic strata for whom the motherhood was not socially accepted. In other cases, poverty was the reason behind child abandonment (Dias, 2008; Leandro, 2011). It has been

observed a strong positive correlation between periods of subsistence crisis and the number of abandoned children. But there was also the possibility of motherhood socially not accepted lead to poverty itself. After arriving to the institution, the child was frequently delivered to a nanny, usually a wet nurse. Most of these women were illiterate and lived in rural areas, working in agriculture (Fonte, 2004).

Not only skeletal samples from such young individuals are found rarely in the archaeological record, but also until now the Faro's sample is the only osteological assemblage from abandoned children to be described and studied. Therefore, it provides a unique opportunity to investigate whether the immature individuals of this institution were exposed to severe environmental constraints. This objective may be attained by the evaluation of their growth and health.

Growth is a graded process that involves various changes related to age, characterized mainly by the increase in size and the differentiation of shape of each part of the body (Ribot and Roberts, 1996; Scheuer and Black, 2000). Its most important aspect is variation due to the complex interaction between genetic and environmental factors (Ribot and Roberts, 1996; Bogin, 1999; King and Ulijaszek, 1999; Scheuer and Black, 2000; Lewis, 2007). Modern studies have shown that growth is considerably adaptable, and can be affected by several factors such as: nutrition, infection, socioeconomic status, urbanization, migration, physical activity, physiological stress, climate, altitude, parasitism, among others (Lewis, 2007). However, the two main groups of environmental stressors that may lead to growth disruption are infection and nutrition (King and Ulijaszek, 1999; Saunders and Barrans, 1999). These two conditions present a complex and intricate interaction. Poor nutritional status induces an immunocompetence decline, while exposure to infectious agents leads to anorexia, malabsorption, elevated basal metabolic rate as a consequence of fever, and protein catabolism needed in the immune response (King and Ulijaszek, 1999). During a stressful

period, the growth rate slows until normal conditions are resumed, with the magnitude of decelerated growth reflecting the severity of the episode (Bogin, 1999; Lewis, 2007). Therefore, individuals reach developmental stages, or biological ages, along the maturity continuum, at different chronological ages (Scheuer and Black, 2000). Given that growth disruptions are cumulative, the older the individual, the larger may be the discrepancy between physiological and chronological ages. Once the child's health condition has been re-established, it has the ability to 'catch-up' with its peers and resume growth at an increased rate. Such ability is impaired with age, and if growth is decelerated for a long period of time, increased growth velocity necessary for 'catch-up' cannot be realized (Lewis, 2007).

Before cessation of growth in height, age may be estimated from several dental and/or skeletal markers.

The dental age estimation is derived from dental development, namely tooth formation and emergence (Moorrees et al., 1963; Ubelaker, 1989). According to several authors (Moorrees et al., 1963; Demirjian et al., 1973), tooth formation is more informative than tooth emergence because the majority of the teeth can be analysed at each examination. In opposition, emergence represents only a specific stage of short duration in the continuous process of dental eruption, or migration to reach the occlusal level. Besides, gingival emergence may be influenced by local and/or environmental factors, such as caries, loss of deciduous predecessors, lack of space in the dental arch, and malnutrition (Moorrees et al., 1963; Demirjian et al., 1973; Alvarez and Navia, 1989). In contrast, the formation rate of the permanent teeth is not affected by early loss of the deciduous teeth and is less prone to environmental stressors (Moorrees et al., 1963; Demirjian et al., 1973; Meinl, 2007; Pinhasi, 2008). Another potential problem with the tooth eruption charts is that, in most clinical research, "eruption" is defined by the emergence of teeth through the gingiva or gum, whereas in skeletal remains is through the alveolar emergence (Halcrow et al., 2007). However,

according to some authors, alveolar emergence in deciduous teeth probably occurs a short time before gingival emergence (Konigsberg and Holman, 1997) and only two months before the occlusion of teeth (Hulland et al., 2000). Regarding permanent teeth, the reported differences in timing between alveolar and gingival emergence are greater: 0.6 years for teeth with deciduous predecessors and 1.4 years for first and second molars (Haavikko, 1970). Therefore, if eruption standards are used in archaeological remains, researchers should be aware of this problematic.

The skeletal age may be estimated from the developmental state of ossification centres and/or from the dimensions of numerous osteological elements (Hoppa and FitzGerald, 1999; Scheuer and Black, 2000; Scheuer, 2002). It is generally observed that dental age is the most accurate indicator in the postnatal period (Hoppa and FitzGerald, 1999; Scheuer and Black, 2000; Scheuer, 2002; Brickley, 2004; Cardoso, 2007; Boccone et al., 2010; Elamin and Liversidge, 2013; García-Mancuso, 2014). A possible reason is that the development of part of the dentition takes place before birth, in a protected environment, whereas skeletal growth and development are exposed for a longer period of time to external factors such as nutritional quality, sanitary conditions, socioeconomic status, and possibly climate and altitude (Bogin, 1999; Hoppa and FitzGerald, 1999; Scheuer, 2002; Cardoso e Garcia, 2009). This difference is the basis of growth-related studies where the children's development is believed to be the reflection of health and nutritional status better than any other index (Lampl and Johnston, 1996; Hoppa e Fitzgerald, 1999; Saunders and Barrans, 1999; Larsen, 2002; Lewis, 2002). Besides, growth of the various skeletal elements may vary in velocity and growth faltering due to different susceptibility to environmental insults (Pinhasi, 2008).

Non-specific stress indicators (e.g. dental enamel hypoplasias and porotic lesions such as cribra orbitalia, cribra humeralis, cribra femoralis, and abnormal porosity) may provide indirect information regarding the health of past populations (Larsen, 2002; Lewis, 2007).

These lesions can arise in the developing child, and with the exception of dental enamel hypoplasias, will disappear if the child recovers (Lewis, 2007). The frequency of these stress indicators by age, the relation between them, and the comparison of their frequencies with both demographic and growth curves may provide more information about the sub-adults' health (Ribot and Roberts, 1996; Larsen, 2002).

The aim of the present study is to compare the pattern of skeletal and dental development of the immature individuals of *Santa Casa da Misericórdia de Faro* in order to know if they were affected by poor living conditions and/or limited access to proper nutrition and health care. Furthermore, the paleopathological profile of these children, namely concerning enamel defects, cribra orbitalia, cribra humeralis, cribra femoralis, porosity, woven bone, osteomyelitis, trauma, endocranial lesions, and other osteolytic and/or osteoblastic lesions, will be drawn to help in the interpretation of their health status.

Material and Methods

The 51 subjects studied were found in poor state of preservation and completeness (Table 1), which hampered the examination.

The following methods were used to estimate the age-at-death: Moorrees and colleagues (1963) for dental calcification; Ubelaker (1989) for the sequence of formation and eruption of teeth; Schaefer et al. (2009) for the skeletal dimensions; Fazekas and Kósa (1978) for the prenatal long bones lengths; Maresh (1970, reviewed by Cardoso, 2005) for the postnatal long bones lengths; and Scheuer and Black (2000) for the development and bony fusion. As already highlighted by Ribot and Roberts (1996), the accuracy of these odontological and osteological methods has been tested by several authors on various American and European samples. Regarding the Ubelaker's (1989) chart, although it has been

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originally created for anthropological work with American Indians, has been approved by the Workshop of European Anthropologists (Ferembach et al., 1980).

Although tooth formation is more informative than the tooth emergence (as explained in the Introduction section) both approaches were used to estimate age-at-death because the macroscopic evaluation of the morphological changes occurring during the formation of teeth is not completely possible unless the walls of the tooth crypts have been damaged, exposing the tooth root and/or crown for observation. Unfortunately, it was not possible to perform a radiographic analysis of the jaws. On the other hand, it will be interesting to see if these two methods of dental age estimation give similar results.

Skeletal measures (in millimetres) were obtained in the left side of the skeleton (or in the right side if the left bone was missing or severely damaged), using a sliding calliper and an osteometric board, following Redfield (1970), Fazekas and Kosá (1978), Buikstra and Ubelaker (1994) and Schaefer and colleagues (2009).

All data were collected blindly by one observer (JP) in two different occasions. In the case of metric data, the intra-evaluator error was assessed by the Technical Error of Measurement (TEM). This index allows researchers to verify the accuracy when performing and repeating anthropometrical measurements (intra-observer) (Perini et al., 2005). For non-metric data, the intra-evaluator error was assessed through the percentage of agreement between observations and also with the Cohen's Kappa coefficient.

All skeletal dimensions obtained for each individual were used to estimate age-at-death. In this case, the age estimation is given by an interval whose lower limit corresponds to the younger age obtained and the upper limit corresponds to the elder age.

In order to compare the estimates of age-at-death obtained by the four methodological approaches, the percentages of agreement between the different ages were compared two by two.

Following Goode et al. (1993), Maresh's data was used to standardize the long bone lengths with the following modification: the long bone data of Fazekas and Kósa (1978) for 10 lunar months individuals to represent the birth (0 year) age class was used.

Several pathological lesions were scrutinized according to Ortner (2003) and Buikstra and Ubelaker (1994): cribra orbitalia, cribra humeralis, cribra femoralis, porosity, woven bone, osteomyelitis, trauma, endocranial lesions, and other osteolytic and/or osteoblastic lesions. Cribra humeralis and cribra femoralis are similar in appearance to cribra orbitalia, but are located in the medial anterior region of the proximal end, near the metaphysis, of the humerus and femur, respectively. Given the high number of bone elements whose poor preservation hampered the observation and since the macroscopic characteristics and aetiology of these lesions are identical, the three types of cribra were grouped with the same general designation: cribra (Miquel-Feucht et al., 2000; Garcia et al., 2002). Following Ortner et al. (1999, 2001), abnormal porosity was defined as a localised condition, in which fine holes, typically less than 1 mm in diameter, penetrate a compact bone surface. Although vascular holes in cortical bone are a normal anatomical feature, these are much fewer in number in a given area and more variable in size, frequently exceeding 1 mm in diameter (Ortner et al., 2001). Abnormal porosity of methaphyses was distinguished from porosity associated with normal remodelling on the basis of the size of the affected area, extending more than a centimetre from the end of the bone (Krenz-Niedbała, 2015). For all available anatomical sites, the lesions were recorded as absent, present or non-observable.

Enamel defects (hypoplasia or others) were investigated following Hillson (2001).

The statistical significance of the recorded values was tested with independent samples chi-square test. Statistical analysis was conducted by using the IBM SPSS statistics® program (version 22.0).

Results

The age estimates obtained by the ossification and fusion of different skeletal elements resulted in too wide intervals and were therefore excluded from subsequent analysis.

Table 2 presents age-at-death estimations for each individual by the three remaining methodologies. As it can be seen, in five individuals it was not possible to estimate age-at-death due to the high level of fragmentation and incompleteness of the osteological elements (Table 1). Therefore, the sample studied hereinafter is composed by 46 sub-adults. These were all under 15 years of age and more than 80% were under 2 years of age.

Regarding the intra-evaluator error for metric data, all relative TEM values were lower than 7.5%, being therefore considered acceptable (Table 3). Therefore, no osteological measurement was excluded from the remaining analysis. For non-metric data, although the values of N were small, both the percentages of agreement between the observations and the Cohen's Kappa coefficients were high for both approaches of dental age estimation, being the results accepted (Table 4). The same occurred in the paleopathological analysis (Table 5).

Table 6 shows the percentage of agreement between the three methods for estimating age-at-death (dental calcification, sequence of formation and eruption of teeth and osteometric data). The age estimates obtained by the methods of dental calcification and sequence of formation and eruption of teeth were absolutely concordant (100%). By contrast, the estimates obtained by osteometric and dental methods showed some disagreement (tooth calcification vs. osteometric: 63.6%; sequence of formation and eruption of teeth vs. osteometric: 80.0%), providing the osteometric methods younger ages.

Standardized long bone lengths are presented in Table 7, following Goode et al. (1993). A strong trend was observed for foetuses and new-borns to present measures very close to or slightly higher than those obtained by Fazekas and Kosa (1978) for the same dental age. On the other hand, older individuals had lower measures that the ones tabulated on

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Maresh (1970, values corrected by Cardoso, 2005). When considering the total sample's average, a slight discrepancy between the upper and lower limbs was recognized, presenting the lower limbs slightly lower values.

The most frequent pathological conditions observed were porosity (Figure 1), woven bone (Figure 2) and cribra (Figure 3). The chi-square test showed that the presence of cribra is distributed similarly in the different analysed bone elements (Chi-square test: 0.345; d.f. =2; p = 0.841), i.e. in the orbital cavity (cribra orbitalia: N observed = 5; 40% affected), humerus (cribra humeralis: N observed = 25; 52. 0% affected) and femur (cribra femoralis: N observed = 22; 45.5% affected). In contrast, the presence of porosity (Chi-square test: 161.538; d.f. =21; p < 0.000) and woven bone varies (Chi-square test: 61.035; d.f. =21; p < 0.000) according to the bone element under analysis. Regarding porosity, the bone elements most affected were: sphenoid; occipital; pubis, ilia, and ischia; temporal; mandible; and humerus (Table 8). The woven bone was more frequently observed in the following bone elements: pubis, ilia, and ischia; humerus; femur; occipital; temporal; mandible; frontal; tibia; and scapula (Table 8).

When evaluating the frequencies of pathological evidences between age-groups (Table 9), a close relation was observed between the estimated age-at-death and the presence of porosity (Chi-square test: 12.846; d.f. =5; p = 0.025) and woven bone (Chi-square test: 14.888; d.f. =5; p = 0.011), being both conditions more frequently observed between the foetal period and the age of 3 years. In opposition, there was no relation between the presence of cribra and age (Chi-square test: 7.269; d.f. =5; p = 0.201).

Diaphyseal lengths of the humerus and femur were plotted against dental ages for each sub-adult, in order to obtain a growth curve (Figures 4 and 5). The dental age estimation method by Ubelaker (1989) was the one that allowed more estimations and consequently the most appropriate to use. In both graphics (Figures 4 and 5), two lines were drawn in order to

compare the stressed children (with several stress indicators) with the less or unstressed children (with only one stress indicator or none). Although the small size of the sample, it is possible to observe in both graphs that the stressed children had smaller diaphyseal lengths than less or unstressed children.

The paleopathological analysis of the sample also revealed two cases that should be mentioned here. One is a two year-old child (individual nr. 27) who presented unusual intracranial marks consistent with bacterial meningitis (for more details about the differential diagnosis see Paredes et al., 2013). And the other is an individual of about 3 years (individual nr. 58) who presented plane-form enamel defects in the occlusal region [in which layers of enamel matrix are missing and a prominent step runs around the edge (Hillson, 2001)], above the contact area, of the labial surface of deciduous lateral incisors. Enamel hypoplasias were also found in the permanent teeth of three other children: individual nr. 7 (1 year ± 4 months of age) had a linear hypoplasia in the upper right canine; individual nr. 46 (7.4-7.8 years of age) had one linear defect in the left lower first premolar; and individual nr. 63 (4.4-5.8 years of age) had two linear enamel hypoplasias in the left lower canine.

No further significant pathological lesions were found in the analysed sample.

Discussion

During growth, each individual has a genetic potential for increasing in size and shape, which depends upon different environmental conditions (Ribot and Roberts, 1996; Lewis, 2007). As highlighted by many authors (e.g. Bogin, 1999; Lewis, 2007; Pinhasi, 2008), several studies on modern populations have shown that low socioeconomic status can significantly affect the growth pattern of a given population. The dental development is less influenced by environment than skeletal development, being considered the best indicator of the chronological age in skeletal remains (Saunders et al., 1993; Cardoso, 2007). Therefore,

the difference between skeletal and dental development may provide a measure of growth and health in a population. However, studies comparing age estimations based on dental and skeletal development in foetal and infant period are not frequent in the osteoarchaeological literature (Lewis, 2000; García-Mancuso, 2014). In this sense, the Faro's sample, comprising immature abandoned individuals, offers a single opportunity to investigate whether these children were exposed to severe environmental constraints.

In the present study, the age estimates obtained by the ossification and fusion of different skeletal elements resulted in too wide intervals, which is in accordance to the already postulated by Pinhasi (2008).

When applying the methods of dental calcification and sequence of formation and eruption of teeth to the Faro's sample, the results were concordant. Given that according to Pinhasi (2008) dental eruption patterns may be more affected by environmental stressors than dental calcification (i.e., delayed eruption may be indicative of high levels of stress) the present results could be interpreted as suggesting that Faro's children did not suffer high levels of physiological stress. However, contrasting to these results, the ages obtained by osteometric and dental methods were different. The disagreement between dental calcification and osteometric data was 63.6% and between the sequence of formation and eruption of teeth and osteometric data was 80% (these different percentages are probably related to the wider age intervals given by the Ubelaker's chart that more easily comprise the age estimation obtained by osteometric data). The fact that linear size measurements of different osteological elements provided younger ages when compared with observations of dental development indicates that growth in Faro's orphans was deviating from the general path which tends to be associated with malnutrition or disease. Moreover, it should be mentioned that in the Ubelaker's chart (1989: 64) "Eruption refers to emergence through the gum, not to emergence from the bone" and, as in skeletons the gums are not present, these estimates could be slightly

higher for deciduous teeth and even higher for permanent teeth. Taking into account the origin and age span of these individuals, such results are not surprising. High rates of infection and malnourishment (related to weaning practices and/or poor dietary quality) affect growth more severely during the period of maximal growth velocity, i.e. between 6 and 35 months of life (Pinhasi, 2008). Besides, the difference between dental and skeletal ages increased with age which is consistent with a cumulative effect of growth constrains. In this sample, it was possible to identify a strong trend for foetuses and new-borns to present very close or slightly higher skeletal measurements than the ones obtained by Fazekas and Kosa (1978) for the same dental ages. The closeness of the results may be related to a more protective environment in utero in comparison to the post-birth life. In contrast, older individuals have lower skeletal measurements than the ones tabulated on Maresh (1970, values corrected by Cardoso, 2005). But, unlike the Faro's sample, the Maresh's tables were developed based on live sub-adults of average to high social status. The differences observed suggest that for Faro's individuals, childhood probably took place with hygiene and food restrictions. Moreover, the older the child the longer he/she would have lived in the institution, being expected a cumulative effect of the environmental constraints. Despite not being possible to be certain about how long these children lived in the institution it is believed that it would depend on their age-at-death, since the *Roda dos Expostos* was used mainly to abandon new-born babies (Fonte, 2004).

According to some authors (Grauer, 1993; Lewis, 2007), if a stress period lasts less than 3 months, the child can compensate the delay by catch-up-growth, but if the problem lasts longer, normal growth may be irreversibly compromised. In other words, catch-up-growth is related to the recovery of normal growth rate, by improved surrounding conditions (Binns, 1998), or a process of habituation of the body to environmental restrictions. Although, at first sight, the Faro's results suggest that growth disturbances lasted long enough to impede

catch-up-growth, as older individuals are shorter for their ages, it should not be ignored that the sample size for this age cohort may not be sufficiently large for this phenomenon to be noted.

Observing the total sample's average, it can be recognized a slight discrepancy between the upper and the lower limbs, the latter being more affected by environmental constraints experienced during development. This same result was also obtained by Sciulli (1994). This may be due to the fact that bones of the lower limb are larger, have greater growth velocity and are more variable for both size and growth than those of the upper limb (Smith and Buschang, 2004). Greater relative lower than upper limb growth has already been reported for foetal (Moss et al., 1955) and postnatal (Maresh, 1959) periods. According to Sciulli (1994), the most rapidly growing long bones are more susceptible to nutritional and disease stress.

Concerning paleopathology, it was noted a higher frequency of porosity and woven bone in younger individuals, particularly those under 3 years of age. It is still possible to see the same tendency in cribra despite the lack of statistically significant differences. Cribra, porosity and woven bone are frequently related to iron deficiency anaemia (Lewis, 2007). However, these lesions can also appear in other deficiency diseases, such as rickets and scurvy, as well as non-specific infections (Ribot and Roberts, 1996; King and Ulijaszek, 1999; Lewis, 2007). In fact, conditions such as malnutrition, dietary deficiency, and increased pathogen load can be on the origin of anaemias (Lewis, 2000). Abundant blood supply in the red bone marrow, especially at the metaphysis of the long bones, makes young sub-adults particularly susceptible to bone infections. Rapid growth in these areas requires a good blood supply which also transports pathogens that rely on iron to achieve their replication potential (Lewis, 2000, 2007). However, the extremely rapid growth during foetal and infancy periods may cause bone porosity, striation and remodelling, turning it difficult to distinguish between

this normal process and a pathological aetiology (Ribot and Roberts, 1996; Lewis, 2000, 2007). In the present study, great care was taken when distinguishing normal and pathological porosity, following the criteria recommended by Ortner et al. (1999, 2001). In fact, when diaphyseal lengths of humerus and femurs were plotted against dental age estimations for each sub-adult, and taking into account the level of stress, it was possible to observe that the very stressed children had smaller diaphyseal lengths than less or unstressed children.

The skeletal parts identified as the most affected by porosity were the sphenoid, occipital, pubis, ilia, and ischia, temporal, mandible, and humerus. Regarding the deposition of woven bone, this was more observed in the pubis, ilia, and ischia, humerus, femur, occipital, temporal, mandible, frontal, tibia, and scapula. In both cases, the most affected elements are some of the largest bones in the skeleton, being therefore more resistant to post-mortem alterations and, on the other hand, more easily analysed.

Apparently there are no differences in the susceptibility of the various bone elements to cribra. According to Miquel-Feucht et al. (2000), the three forms of cribra (orbitalia, humeralis and femoralis) are similar lesions, sharing macroscopic, microscopic and radiographic characteristics, related to pathologies with the same aetiology. One of the possible aetiologies is anaemia, either of genetic, infectious, or nutritional origin. However, it should be noted the high number of bone elements whose poor preservation made the observation impossible.

The paleopathological analysis of the Faro's sample also revealed plane-form enamel defects in an individual of about 3 years of age. Dental enamel hypoplasias are a non-specific stress indicator. Among the conditions that have been shown to cause these enamel defects are fever and starvation (Hillson and Bond, 1997; Lewis, 2000). Exposed-plane-form defects are more commonly found in the occlusal part of the crown, being the most noticeable manifestation of enamel hypoplasia. They presumably represent a pronounced growth

disruption (Hillson and Bond, 1997). Although several studies have tried to assess the age at which a defect was formed by measuring the distance between the defect and the cemento-enamel junction, Hillson and Bond (1997) argued that the position of the hypoplasia is more an expression of the pattern of enamel layers than the timing of a particular stress episode. Besides, the extent of an exposed-plane-form defect frequently has no relation to the duration of the stress episode that was in its origin (Hillson and Bond, 1997).

Child growth standards and non-specific stress indicators are frequently used as measures of the general health status of a community since their growth, development and diseases are sensitive indicators of the quality of the socioeconomic environment in which they live (Johnston and Zimmer, 1989; Bogin, 1999; Lewis, 2007). Child survivability depends greatly on the surrounding environment, in particular, the level of sanitation and availability of healthcare facilities (Lewis, 2007).

In the Faro's skeletal sample of abandoned children both growth and paleopathological results suggest unfavourable conditions, expected when food and hygiene were scarce as mentioned in historical documents (Fonte, 2004; Dias, 2008). The exposed children were subject to more risks than other children. These risks were diverse, namely, malnutrition, high probability of contracting infectious diseases either by contact with wet nurses or with other children, neglect and maltreatment (Dias, 2008). In the first months/years of life, malnutrition was mainly due to weaning. Sometimes, new-borns were breastfed by their wet nurses, but in many cases, the caregivers were themselves malnourished or had no milk. In these cases, young babies were fed with dairy cattle's milk (of cow, goat or donkey) (Fonte, 2004). In addition to the lack of the most basic health and hygiene practices and the absence of prophylactic measures and alternative forms of artificial feeding, the institutions and the family care homes did not meet the minimum living conditions. Without water and sanitation, most of these homes would consist of unhealthy spaces, sometimes contiguous

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with the cattle's stables. All this obviously could propitiate infectious diseases and lead to a premature death of the exposed children (Fonte, 2004). In the present study, and regarding paleopathology, the relatively high frequency of porotic injuries and new bone deposition corroborate the poor conditions experienced by the *Santa Casa's* orphans during their short life.

Conclusion

The Faro's sample provides the first opportunity to learn more about children who were abandoned in the south of Portugal through the foundling wheel in the 16th-19th centuries. Not only are there few skeletal samples from such young individuals in the archaeological record, as well as until now the Faro's sample is the only osteological assemblage from abandoned children in the world to be described and studied. Despite the impossibility to infer a specific aetiology for the observed paleopathological lesions or even to understand how the analysed skeletal stress indicators are related to each other, the detailed study of growth and health of the individuals who make up this sample is extremely important for a better knowledge of the living conditions and the degree of stress imposed to the children delivered to *Santa Casa da Misericórdia de Faro* at that time. In sum, the fact that age estimates obtained by osteometric gave younger ages than the dental methods suggests that these individuals experienced great difficulties during their short life. Moreover, the paleopathological data, namely the high frequency of porotic lesions and new bone deposition, especially in the individuals previously identified as small for their age, corroborate this conclusion. Hence, we believe this study enriches the scanty osteoarchaeological documentation of both growth and health in abandoned children, and it can contribute to reduce the discrepancy between historical and biological evidences.

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Acknowledgements

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