UNIVERSITY OF READING

DYING YOUNG – A PALAEOPATHOLOGICAL ANALYSIS OF CHILD HEALTH IN ROMAN BRITAIN

Submitted for the Degree of Doctor of Philosophy

DEPARTMENT OF ARCHAEOLOGY – SCHOOL OF ARCHAEOLOGY, GEOGRAPHY AND ENVIRONMENTAL SCIENCE

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DECLARATION OF ORIGINAL AUTHORSHIP

"I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged."

Anna Rohnbogner

ABSTRACT

Children represent the most vulnerable members of society, and as such provide valuable insight into past lifeways. Adverse environmental conditions translate more readily into the osteological record of children, making them primary evidence for the investigation of ill-health in the past. To date, most information on growing up in Roman Britain has been based on the Classical literature, or discussed in palaeopathological studies with a regional focus, e.g. Dorset or *Durnovaria.* Thus, the lifestyles and everyday realities of children throughout *Britannia* remained largely unknown. This study sets out to fill this gap by providing the first large scale analysis of Romano-British children from town and country. The palaeopathological analysis of 1643 non-adult (0-17 years) skeletons, compiled from the literature (N=690) and primary osteological analysis (N=953), from 27 urban and rural settlements has highlighted diverse patterns in non-adult mortality and morbidity. The distribution of ages-at-death suggest that older children and adolescents migrated from country to town, possibly for commencing their working lives. True prevalence rates suggest that caries (1.8%) and enamel hypoplasia (11.4%) were more common in children from major urban towns, whereas children in the countryside displayed higher frequencies of scurvy (6.9%), cribra orbitalia (27.7%), porotic hyperostosis (6.2%) and endocranial lesions (10.9%). Social inequality in late Roman Britain may have been the driving force behind these urban-rural dichotomies. The results may point to exploitation of the peasantry on the one hand, and higher status of the urban population as a more 'Romanised' group on the other. Comparison with Iron Age and post-medieval non-adults also demonstrated a decline in health in the Roman period, with some levels of ill-health, particularly in the rural children, similar to those from post-medieval London.

This research provides the most comprehensive study of non-adult morbidity and mortality in Roman Britain to date. It has provided new insights into Romano-British lifeways and presents suggestions for further work.

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CHAPTER 1. INTRODUCTION

1.1. BACKGROUND AND RATIONALE

Archaeological research into Roman Britain has mainly focussed on the architectural grandeur of the large towns and high status *villa* settlements, and means of quantifying the 'Roman-ness' of said sites (e.g. Wacher 1974; Burnham and Wacher 1990; Mattingly 1997, 2006; Parkins 1997; Millett 1999, 2001, 2005; Burnham et al. 2001; James 2001; White and Gaffney 2003; Pitts and Perring 2006; Pearce 2008; Holbrook 2015). However, the archaeology of general rural settlements, such as villages and farmsteads, and their inhabitants is now receiving much needed academic attention, and is pivotal in obtaining a more holistic view of Britain under Roman rule (e.g. Millett 2001, 2005; Mattingly 2004; 2006; Taylor 2007; McCarthy 2013; Breeze 2014; Fulford and Holbrook 2014, also see 'The Rural Settlement in Roman Britain' project at the University of Reading available online via the Archaeology Data Service http://archaeologydataservice.ac.uk/archives/view/romangl/). The lifeways of the Romano-British population are yet to be fully explored, especially for those living in the countryside. New insights into what it was like to live in Roman Britain have raised opposing views on the urban-rural dichotomy, and it is of interest to explore these further (Mattingly 2006). Contrary to the long-held belief in the detrimental effects of the urban environment on its inhabitants, recent bioarchaeological research by Pitts and Griffin (2012) on health in urban and rural settlements throughout Roman Britain, and Redfern et al. (2015) in Dorset, has demonstrated that living in the countryside also negatively affected its residents. It is therefore necessary to evaluate the extent to which the late Romano-British *villa* economy affected the peasantry, and whether the urban environment was in fact as taxing on health as previously believed.

Palaeopathological studies of the adults who lived and died in Roman Britain have provided a direct insight into health, diet and the lifeways of the Romano-British population, albeit with a bias towards those recovered from urban cemeteries (Roberts and Cox 2003). Most importantly, what is still lacking is a comprehensive picture of what it was like to grow up in Roman Britain. Child health is a very powerful indicator of overall population health and dynamics, as children are dependent on others. As children are growing, they will reflect adverse environmental conditions more readily than their parents (Mensforth et al. 1978; Lewis 2007). Childhood remained a neglected theme in archaeological research until fairly recently, with scholars only gradually becoming aware of the benefits of studying children within both social and scientific archaeological agendas.

Awareness of children as independent social agents in the past, and recognition of their material culture and the spaces they inhabited is now enabling us to ‘see’ children more clearly in the archaeological record (Scott 1992; Baker 1997; Gowland 2001; Baxter 2005, 2006a; Kamp 2006; Kraus 2006). However, children’s space and their material culture aside, the only unambiguous record of a child in the past is the skeleton. Roman archaeology is no different from other branches of the discipline in its research concerns, and Romano-British childhood has only evolved as a dedicated subject in Roman scholarship over the past decade.

There is a wealth of information on childhood in Rome itself, by means of consulting the Classical literature, and epigraphic or iconographic references (e.g. Rawson 1966, 1986, 1991, 2003a,b; McWilliam 2001; Harlow and Laurence 2002; Revell 2005; Harlow et al. 2007; Laes 2004, 2007; Crummy 2010; Mander 2013). This approach is weakened by the somewhat anecdotal undertones particularly in the written sources (Pearce 2001a; Laes 2007, 25). The vast majority of these texts stem from elite men of the Republican or early Imperial period, often retired and pursuing a philosophical recital of matters relevant to their own sphere of being (Ireland 1986, 3-4). By supporting the study of childhood solely via Classical sources, research is purely based on individual accounts of a privileged minority. This may represents the truth for only a fraction of society or simply be a philosophical metaphor of idealised daily conduct (Garnsey and Saller 1987, 108-115; Garnsey 1991). It is therefore very difficult to pinpoint the everyday realities for a child in Rome, let alone at the northwestern fringes of the Empire several centuries later. An additional caveat is that the majority of the population, the working class, peasantry and slaves, found themselves at the bottom of the social hierarchy and hence received very little to no mention within these texts (Bradley 1984, 77-79; Garnsey and Saller 1987, 114-120; Mouritsen 2011, 129).

Particularly in Roman Britain, inscriptions and imagery of children are scarce and cannot fully communicate life histories of children from all orders of society in both town and country (Burn 1970; McWilliam 2001; Tomlin 2003; Revell 2005; Laes 2007). Yet, we have to be aware of the life course of children from Rome itself, as certain aspects such as the uptake of weaning practices, may be detectable in the palaeopathology of Romano-British children.

Important insights into child health in Roman Britain have been provided by a number of palaeopathological studies by Redfern (2007), Lewis (2010, 2011, 2012) and Redfern et al. (2012). These studies have highlighted a decline in child health from the Iron Age through to the Roman period in Dorset, and likened some of the disease patterns observed in the Poundbury Camp cemetery at *Durnovaria* to those seen in post-medieval children (Lewis

2010). The compromised health observed in these children has been interpreted as an indicator for the uptake of certain aspects of Roman weaning and early childhood feeding practices. This observation has also been confirmed isotopically in the children from the Queensford Farm/Mill cemetery at Roman Dorchester-on-Thames (Fuller et al. 2006a; Nehlich et al. 2011), children from Roman Dorset (Redfern et al. 2012), and from Roman London (Powell et al. 2014). However, these studies have a regional and urban focus, and fail to provide a holistic picture of life in Roman Britain or to enable a comparison between urban and rural health to be made. The lifestyles and everyday realities of children (defined as non-adults aged 0-17 years) throughout *Britannia* need to be explored by evaluating patterns of ill-health in both urban and rural settlements spread across England.

1.2. RESEARCH AIMS

- To provide a national overview of non-adult palaeopathology across Romano-British sites in England, to demonstrate the value of this approach in elaborating on lifeways in Roman Britain without over-reliance on the Classical literature.

- To acquire new insights into everyday lived realities of children in both urban and rural settlements and contextualise the levels of ill-health observed at Poundbury Camp in relation to other Romano-British settlement contexts.

1.3. OBJECTIVES

The aims of this thesis will be achieved by:

- Compiling non-adult palaeopathological data from secondary sources including (un)published skeletal reports and the grey literature.
- Acquiring new data through the primary analysis of 1000 non-adult skeletons from urban and rural sites.
- Revising age categories used for describing morbidity and mortality in Romano-British children.
- Comparing urban-rural trends in health within their respective sociocultural environment.

1.4. THESIS OUTLINE

An overview of the scholarship of childhood in archaeology, and how this has led to the palaeopathological study of non-adult remains is important for grasping past and present developments in our understanding of childhood in the past (Chapter 2). Trying to answer what it was like to grow up in Britain during the Roman period, previous palaeopathological studies of children are reviewed, before diverting our focus to Rome itself. Reviewing the textual evidence is important for providing a basis for potential patterns observed in ill-health, disease and stress in Romano-British children, which may have arisen from following Roman childcare practices or developmental milestones in the socialisation of children (Chapter 3). Methods for skeletal ageing and the diagnosis of palaeopathological conditions in children are presented, alongside a brief overview of each site included in the analysis (Chapter 4). The results for mortality and morbidity in the combined dataset including the author's data and the data extracted from the literature are presented as an overview. A detailed outline of patterns in mortality, growth, ill-health and stress are given for the primary study sample analysed by the author, allowing an in-depth consideration of childhood health in Roman Britain (Chapter 5). A brief outline is provided on the distribution of palaeopathology in relation to the mode of burial, to evaluate whether there is a link between certain burial rites attributed to children and the ailments they suffered from whilst they were alive (Chapter 6). The results of the palaeopathological analysis are then discussed, with the combined study sample providing a broad overview of childhood health, and the primary study allowing exploration in more detail. Health and disease are considered under several themes, including infant mortality, growth, dental health, diet, working lives and adolescence, and evidence for exploitation of the peasantry. It was also deemed important to briefly consider Roman-British childhood health in context by comparing the patterns observed in the primary study sample with those seen in Iron Age Dorset and post-medieval London (Chapter 7). Lastly, conclusions are drawn, highlighting the processes that shaped childhood and health in Roman Britain, with a recommendation for future work (Chapter 8).

CHAPTER 2. THE ARCHAEOLOGY OF CHILDHOOD

This chapter reviews the trends and challenges in the study of children in social archaeology. This is followed by a presentation of how the archaeology of Romano-British child burials has added to the current knowledge on growing up in Roman Britain. Moving beyond the purely artefactual and funerary evidence for the life course of Romano-British children, palaeopathological approaches are presented as a valuable indicator for health and disease in past populations.

2.1. CHILDREN IN SOCIAL ARCHAEOLOGY

2.1.1. Childhood theory in social archaeology

Children and women were believed to have been marginalised in past populations and were rendered archaeologically invisible (Weber-Kellermann 1987; Scott 1992; Baker 1997, 183; Lillehammer 2010). Archaeologists were concerned with the more prominent 'dominant male', rather than those seen to be operating in the background or the domestic space (Baker 1997, 184-185; Gowland 2001). The wealth of information retrievable from non-adult skeletons has been largely ignored in favour of studying artefacts or means of burial (Chamberlain 1997, 248; Kraus 2006, 1). Baxter (2005, 8) suggested that children initially received attention as independent and important agents in the past when artefacts that could not be categorised were attributed to the activity of children.

Derevenski (1997, 193-194) warned against inference of the Western construct of childhood as a stage of dependence and insignificance in comparison to the agency of adults. Socialisation is a cultural process that can serve as a vehicle for gauging the changes, continuity and sustainability of a population and its culture which rests on the successful training, education and moulding of children into social agents. Envisaging this process will yield valuable information on the functioning of a given society and can only be achieved by approaching children archaeologically (Baxter 2005, 32-34). Awareness of socialisation in a past society may give insights into the division of labour, birth spacing, scheduling of resources, mobility and organisation (Baxter 2005, 10-11). Scott (1992) considered that both identity and the quality of 'being social' stem from cultural decisions, which will ultimately influence the shaping and interpretation of archaeologically visible conduct relating to infancy and childhood. If, for example, children are considered to contribute little to a culture, their imprints in the archaeological record are likely to be overlooked in favour of the socially more prominent adult identities. Many believe that children were independent social agents that consciously influenced their surroundings, were expected to hold responsibilities for their kin and community. Children contributed to the economic strength of their population, aspects which can be seen in ethnographic parallels (Derevenski 1997, 193; Baxter 2005, 11, 15; 2006a; Bugarin 2006; Kelly 2006; Schwartzman 2006). Lillehammer (1989; 2010) advised to view the world from a child's perspective. This approach aids in recognising the culture created by the child via interaction across three social levels (Sigsgaard 1979, 128). Lillehammer (1989) described these as the culture created via interaction of the child with the environment, and the two forms of culture transferred from adult to child and across the children themselves.

A pivotal aspect of children's social agency is child labour, which is prevalent in societies both past and present. Our thinking is inherently influenced by the peculiarly Western viewpoint that child welfare and education can only thrive when children's workforce is not essential to economic stability of the family (Kamp 2001). Some may apply this observation to Roman society; the higher the social standing of the family, the more likely the children were to receive education. More recent research into Roman childhood however indicates that children were expected to fulfil chores as part of their education and training, which may be interpreted as child labour from a modern viewpoint (Laes 2011a, 218). In Iron Age Britain, status may have also influenced the likelihood of a child being trained in prestigious professions, which may be visible in the burial record and may have influenced later Romano-British traditions (Shotter 1998, 67-68; Karl 2005).

2.1.2. Children as entities in the archaeological record

The lack of focus on children in archaeological theory and practice until recently could have two distinct causes. It may be a reflection of their absence, or our inability to see indicators of childhood within the archaeological record as they may be less tangible (Chamberlain 1997, 248; Derevenski 1997, 193). The archaeological record itself is flawed with incomplete samples, which provide us with a skewed view of the past, potentially even more so when looking for the children (Chamberlain 1997, 248). However, the incorporation of anthropological methods and approaches has provoked a more in-depth consideration of children as archaeological entities, as the only unambiguous record of a child in the past is the skeleton (Kamp 2001; Baxter 2005, 19; Schwartzman 2006).

Baxter (2005, 11) advocated a scholarship that appreciates children in past societies as active participants in the economic, social, religious and political life of their community. Children and adults should be regarded in a similar light with respect to their agency, as both children and adults are neither entirely under the control of others, nor are they fully independent (Kamp 2006). The definitions of the categorical chronological and social connotations of childhood have to be negotiated for each individual cultural context rather than universally assumed before reflecting on it using archaeological means: age identities are not uniform, and their fluidity impacts on the expression of gender (Scott 1991; Gowland 2001; Baxter 2005, 24). The researcher's own understanding of the terms 'childhood' and 'children' is crucial, especially since Western definitions of aspects of childhood are simply one of many (Schwartzman 2006; Lewis 2007, 4).

2.1.3. The archaeological visibility of socialisation and development

2.1.3.1. The material culture of children

The manifestation of children's behaviour and attitude in objects is at the heart of archaeological scholarship, stipulating toys as the material culture of children (Baxter 2005, 40-41). This approach investigates the nature, usage and consequences of toys, as well as the spatial distribution of children's material culture (Calvert 1992; Baxter 2005, 42-58). However, children create playthings themselves and their creativity in play is not limited to items that we might describe as toys (Wileman 2005, 27). These include household items, tools or discarded objects, some of which can neither be identified nor seen in the archaeological record. A toy should not be seen as a static object but rather a fluid and context-related concept. Examples are children playing with stones or sticks, which may leave archaeologically discernible traces, although these items do not fall into current definitions of toys (Crawford 2009). Simply labelling all miniature items as toys is therefore naive (Foxhall 2000; Lewis 2007, 10). Apart from toys, there are additional objects and material culture indicative of children, such as fingerprints (Baart 1990; Kamp et al. 1999) and tooth marks on artefacts (Aveling 1997), as well as hand- or footprints (Roveland 2000; Kralik et al. 2008), finger markings (Franklin and Habgood 2009), and death masks (Coulon 1994). Other means of looking for children archaeologically are based on children copying adult behaviour and actions as a part of learning. This process can be visible as tools and objects that may be smaller, but of poor craftsmanship compared to the adult equivalent (Malina 2004; Baxter 2005, 50-55; Lewis 2007, 9). The developing cognitive and motor skills of children will not allow for perfect replication of adult material culture (Kamp 2001; Malina 2004; Baxter 2005, 53; 2006a; Bugarin 2006). However it can also be argued that material culture of a lesser standard may be assigned to unskilled novices (Finlay 1997; Kamp 2001). Tables 2.1. summarises milestones in the development of cognitive, intellectual and motor skills. The cognitive and physiological developmental stages will impact on a child's definition of, and engagement with toys and the quality of the imitation of adult material culture. Similarly, these stages will dictate how and when the child interacts with the environment, and how the social agency of a child changes through the life course which may be detected archaeologically as well as osteologically.

It is proven within the ethnographic context that some cultures see their offspring as miniature adults. Park's (1998) discussion of the archaeology of children within Inuit societies in light of miniature material culture, for example, is valid. Yet again it is not advisable to assume this construct to be true for every archaeological population (Baxter 2006a). As Kraus (2006, 44) recommended, ethnographic analogies may be useful indeed, however, the researcher applying these models has to be cautious as to their validity in light of possibilities rather than certainties.

Table 2.1. Main stages of childhood based on cognitive and intellectual development

Stage and age range	**Behavioural development**
Stage I (birth-18/24 months) sensorimotor/infancy	Behaviour is instinctive and reflexive, the baby acquires basic motor habits but lacks language and cognitive skills
Stage II (2-7 years) preoperational/early childhood	The child displays intuitive intelligence and spontaneous inter-personal feelings
Stage III (7-11/12 years) concrete operational/middle childhood	The child is capable of concrete intellectual operations and displays a moral sense and the ability to engage in social and cooperative behaviour
Stage IV (11-12 years) formal operational/adolescence	The child is capable of abstract intellectual operations and the individual's personality is fully formed. The child approaches sexual and physical maturity during this stage and can act effectively in social and ritual behaviours alongside adults

(adapted from Wileman 2005, 162)

2.1.3.2. Children's space in archaeology

Due to their initial consideration as an archaeological entity within gender studies, children were connected to the same space as women (Baxter 2006b). However, children occupy different spaces, whilst also having a distinct effect on space (Baxter 2005, 68; Baxter 2006b). Yet, it may be assumed that the archaeologically visible effect of a child on space is more strongly expressed closer to home or in the domestic space, and weakens further away from home in space that becomes increasingly public (Moore 1986).

It has been suggested that children have a distorting effect that may alter the formation and constitution of a given site (Baxter 2006b). More research is however required to standardise these principles and yield a methodology that appreciates the unique formation processes of individual sites. Allison (2004, 155-156) for example, pointed out the difficulties associated with identifying the material culture produced and space inhabited by children from excavations at Pompeii. It was noted that evidence for a dedicated children's domestic space was absent, neither could a specific children's material culture be defined.

2.1.4. Children in the burial record

The treatment of children in death awarded by their mourners is viewed as indicative of the positions these children inhabited during life, as culturally significant stages in the lifecycle are believed to be reflected in mortuary practice (Kamp 2001; 2006). Funerary archaeology is a widely accepted approach to grasping childhood in the past. Burial archaeology allows us to recognise phases of the life course, as well as gendered age thresholds by use of artefacts (Gilchrist 2000, 326-327). Examples are a particular style of jewellery only worn by married women, or men carrying weaponry once they have reached adulthood.

Yet, an interpretation of the child's attributes based solely on grave goods may be wrong, since the social persona of the interred child does not necessarily reflect his or her biological sex and chronological, biological or social age. Grave goods and the mode of burial are a product of behaviours of the mourning community (Kraus 2006, 6). Simply noting the presence, absence or nature of grave goods is not sufficient, the materials used and positioning of the artefacts are equally important (Crummy 2010). Rega (1997, 234) demonstrated that children and females at a Bronze Age cemetery in Serbia exhibited an overlap in gender identity reflected in their grave furnishings. Strictly engendered grave goods classed as tools were found with children who were developmentally not mature enough to use them, in this instance items associated with females. This indicated that children until the age of seven years old were gendered as ‘female’. Young females and older women were afforded the same burial rites, whereas boys were awarded gendered grave goods at a later point. The gender ratio was still biased, indicating that boys were indeed gendered as female (Rega 1997, 233-234, 240). This study demonstrated how children may be wrongly identified as female when sex is purely based on grave goods, reinforcing the static nature of male gendered identity as opposed to fluid gendered constructs of women and children.

Veit (1996, 204-207) interpreted funerary rites of children in a very practical light, attesting that their mortuary treatment is an economic reduction of the adult equivalent, which in turn is reflective of their diminished social status. Alternatively, a number of other key points may be considered. The respective society is aware of the dying of children to an extent where children demand a distinct set of burial rites. The children may not have actively contributed to society, yet they possessed attributes that required and necessitated particular burial rites, and the value of children may have been connected to their potential life course, rather than the actual shortened life history. These in turn suggests that their funerary rites are translated into an appreciation of the incomplete life course (Kraus 2006, 10).

It should also be emphasised that burial is a specific moment during which gender, society and their agents are constructed (Keegan 2002, 29). Burial may be interpreted as self-representation to a certain degree, encompassing the individual’s identity and gender during life. However, burial may also represent an individual’s identity as seen by those who carried out the funerary rituals. Burial should be construed as a strategy by those in charge in order to provoke a specific interpretation of the cultural context of an explicit social construct. The appearance in death therefore serves a primarily communicative function and is quintessential for demonstrating identity (Keegan 2002, 29-31; Rosten 2006, 175).

2.1.5. The archaeology of Romano-British child burials

Although earlier inhumations are known, inhumation as the standard burial practice was introduced in Roman Britain from the Continent during the 2nd century AD. The practice continued to be rare and limited to cemeteries of larger urban settlements until the 3rd century AD. However, by the end of the 4th century AD, inhumations had become the preferred mode of burial. Cemeteries were arranged in neat rows, grave goods had become scarce and coffins became more common, with most bodies supine and placed along a west-east axis (Taylor 2001a, 109). Since most burials in the Romano-British period are believed to be associated with settlement boundaries, i.e. beyond the town walls, a probable sampling bias is introduced for burials located elsewhere, as these areas may not feature in excavation strategy (Pearce 1999a; 1999b, 154). This point is of particular importance with regard to infant burials as they tend to be associated with building structures of the settlement itself, besides boundaries of the settlement and formal burial grounds. If this possibility is not considered in the excavation strategy, the small infant burials are easily missed. Simultaneously, if only the settlement rather than the cemetery itself is excavated, chances are the majority of skeletal remains will be those of infants (Pearce 2001a). Grave goods are considered vital for dating hence there has been greater interest in furnished graves. Pearce (1999a; 1999b, 152) also argued that there is bias due to the prominence and visibility of different site types. Larger lowland settlements with enclosure ditches are archaeologically more visible (Pearce 1999a; 1999b, 152), which in turn evokes interest and further work. Whereas smaller rural sites and their respective cemeteries may be more easily overlooked, or are considered too small or insignificant to warrant excavation and analysis.

Differential spatial distribution of infant, child and adult burials has been first discussed by Ucko (1969). Ethnographic parallels support a hypothesis based on the child's limited social persona as promoting the withholding of full burial rites, including the separation of adult and non-adult burial space (Ucko 1969). Practices like these do not necessarily support a theory of emotional detachment and callousness by the parents as a coping mechanism to perinatal or infant death (Pearce 2001a; Gowland et al. 2014). The ethnographic record indicates that withholding of extensive mourning and burial rituals is not a reflection of the actual emotional turmoil, grief and distress experienced by the family (Wembah-Rashid 1996, 77; Gowland 2002, 197). Grief can be expressed in a range of emotions, and even in societies where pregnancy loss and infant and child mortality are high, it would be insensitive to ascribe a general lack of parental attachment (Meskell 1994).

Some Romano-British sites have been identified with 'infant cemeteries' for those aged 6 months-1 year old and below. Examples are Barton Court Farm in Oxfordshire, Hambleden in Buckinghamshire, Bradley Hill in Somerset and Malton in Yorkshire (Esmonde Cleary 2000, 135). These are mainly *villa* sites apart from Malton which was described as both a Roman fort and civilian settlement (Wenham 1974). If these infant cemeteries were a general practice in late Roman Britain, potentially every settlement will have such a burial ground. Previously excavated sites would have to be revisited and the current understanding of Romano-British cemetery analysis revised. Scott (1999) published a review of infant burials and funerary practice in late Roman Britain. The high incidence of infant and child burials compared to earlier time periods has sparked theories on infanticide, ritual or hurried disposal (Scott 1992; 1999, 114; Mays 1993; 2003; Mays and Faerman 2001; Pearce 2001a; Taylor 2001a, 92;

Carroll 2011, 168-175; Bonsall 2013a). Raised mortality of the very youngest is a given in pre-industrial societies and can still be observed at present (Becker 1995). Equally, higher archaeological visibility does not necessarily suggest higher mortality or deliberate death (Scott 1992). Intramural burials, especially in association with houses are more prevalent on rural sites. Burials are mainly encountered clustered or individually in the walls, foundations or under the eaves of domestic dwellings or structures associated with agricultural activity such as barns and corn-driers (Scott 1991, 120; 1992; Millett and Gowland 2015). The reasons behind this mode of burial are wide-ranging and remain debated. Scott (1991, 120) hypothesised that these burials are representative of women's ritual strategies. Burying infants within houses, barns and yards may have served to liberate women from socially gendered constraints and demonstrated a means of emphasising a link between agricultural activity and space with a woman's sphere. It has also been suggested that these infants are foundation burials associated with beliefs and superstitions (Philpott 1991, 100-101). Pearce (2001a) attested wide-ranging diversity and complexity to the location of infant burials. By consulting the Classical literature and burial evidence, he noted both parallels and contradictions. *Mors immatura* was a dreaded fate, however writers such as Pliny and Juvenal advise to refrain from excessive mourning for a deceased baby and differential burial rites. Yet the burial record proves that infants were not universally treated as marginal, with some cemeteries including the very young, whereas other burial grounds are practically devoid of infant burials (Pearce 2001a). Similarly, the changing marginality of infants in life and death is also reflected in the epigraphic record with only very few examples of epigraphic commemoration of infants (Hopkins 1966; Derks 2014). More recently, Millett and Gowland (2015) attested that these burial clusters are a reflection of close ties between mother and child, and may have served to maintain a bond and proximity beyond death. This reasoning prompts us to consider infant burial within the settlement boundaries as a distinct funerary ritual reserved for this age group (Gowland et al. 2014). Overall, this is not unusual. Infants are often interred separately from adults and older children, both in the past and at present. Finlay (2000), for example, gave a chronological overview of infant burials in Ireland and pointed out the long held tradition of burying unbaptised children away from baptised members of the community. The liminal state of the unbaptised infant's soul is regarded as the underlying reason warranting a separate social status in death.

Infants were also recovered from rubbish- and cess-pits at Greyhound Yard in Dorset, or town houses in urban settlements, for example at Cirencester in Gloucestershire, and *Verulamium* in Hertfordshire (Frere 1983, 238; Bayley and King 1986; Rogers 1993). These finds demonstrate that infant burials in unusual locations are not necessarily limited to smaller rural settlements and *villa* sites. Late Roman Silchester, Hampshire, showed evidence for deliberate placement of neonate bones in pits, potentially linked with ritual objectives. The deposits contained a range of animal bones including dogs, which indicate use of these pits for disposal of not just household waste. However these pits contained mainly isolated baby bones, an unusual pattern for later Roman periods (Snelling 2006, 204; Fulford 2006, 271-272). This conduct may be suggestive of a change in beliefs and ritual behaviour, possibly linked to native pagan influences. During the 4th century AD, Watts (1998, 74) claims a resurgence of pagan burial rites. Separate burial of infants and the attribution of lesser rites were apparent in the Iron Age (Cunliffe 1993, 196). Hence these 4th century practices may be an amalgamation of both earlier pagan and Roman ideologies. Native ideas and subsequent interment of infants within building structures may have found more of a following in rural areas since Roman influence and policy may have held a lesser influence. Keeping the infant within the close vicinity or under the shelter of one's home may have signified the unbaptised infant not having to enter the afterlife unaccompanied, or presenting the opportunity for continuation of the soul or spirit linked with fertility (Finlay 2000; Tibbetts 2008; Chadwick 2012). Roman occupation brought about a change in agriculture, presenting the native population with new means of harvesting and processing (Millett 1990, 202). Chadwick (2012) pointed out how past societies shared different perspectives on fertility and agriculture than we do today. Plants and animals were depended on for reciprocal benefit rather than exploited and dominated. Incorporating a dead infant back into the earth in a space that was agriculturally managed may have served as a link in a cycle of interdependence between the community and the land.

Classical sources describe infants as lacking identity and personality, therefore possessing reduced social significance within the cultural community (Philpott 1991, 101). By consulting Pliny (*Nat. Hist.* VII, 15) we are informed that infants are devoid of a soul until teething. Infants dying prior to teething shall not be cremated but inhumed within the settlement boundaries or under the eaves of buildings. The Roman concept of an infant's differential status in life and death may have gained acceptance and a following in Roman Britain. Teething brings about a range of behavioural and developmental changes in the infant, such as restlessness and hand-, lip- or object-biting (Sarrell et al. 2005). This change in temperament and responsiveness, coupled with the ability to ingest more solid foods may have been interpreted as the infant gaining a persona. The inclusion of infants in late Romano-British 'Christianised' cemeteries alongside practices such as intramural interment and burials in clusters within separate infant graveyards potentially indicate a change in attitude (Philpott 1991, 101; Scott 1992). Signs of differential treatment of infants and perinates still persist even in the later stages of Roman Britain, but burial patterns, especially relating to larger urban sites indicate a more uniform treatment of adults and non-adults (Pearce 2001a). The view of infants as somewhat incomplete beings may have been abolished in favour of a more Christian attitude which attributes a soul to every human being and therefore warrants inclusion in the formal cemetery, albeit in specified areas at times.

It is disputed when gender becomes relevant and archaeologically discernible within the funerary ritual of children in Roman Britain (Kraus 2006, 13). Theoretically, the ageing and maturation process leave archaeological traces outside of the mortuary context via initiation rites and the life course, such as marriage (Kamp 2001). This clearly demonstrates where the current shortcomings of children in social archaeology lie, as age profiles and biological sex can only be discerned by analysing the skeletons themselves rather than just the artefactual or funerary evidence in isolation.

Recent work in the archaeology of children in Roman Britain, exploring the life course and social construct of childhood, has been undertaken by Gowland and Redfern (2010), Redfern and Gowland (2012), Redfern et al. (2012), Gowland et al. (2014) and Millett and Gowland (2015). The authors draw on anthropological investigation of non-adult skeletons, discussing morbidity and mortality, and incorporate archaeological approaches. Papers by Gowland and Redfern (2010) and Redfern and Gowland (2012) are important milestones in the Romano-British archaeological literature that emphasise the importance of non-adult bioarchaeology towards a better understanding of the non-adult life course as described in the textual sources from Rome itself. Redfern et al. (2012) integrated bioarchaeological data with isotopic findings to reconstruct dietary patterns of non-adults from Roman Dorset. Although of very high informative value, isotopic studies are expensive and often out of the research budget. Gowland et al. (2014) and Millett and Gowland (2015) present holistic discussions of infant mortality in Roman Britain, with an appraisal of the bioarchaeological evidence drawing on the Classical sources, ethnographic parallels and burial rites.

When discussing children in Roman Britain, Gowland and Redfern (2010) and Redfern and Gowland (2012) have emphasised the importance of viewing growing up and growing old within the individual social context. Age does not simply comprise of a chronological component but involves biological and social milestones which may not always complement each other (Ginn and Arber 1995, 5-7). The duration of childhood and adolescence in Rome was differentiated by chronology and gender, but both social and economic status will have affected the life course too (Gowland and Redfern 2010). It is accepted that the Roman ideology of age exhibited regional variation across the Empire, which requires a life course approach to the study of age and ageing (Revell 2005; Redfern 2007;2008; Harlow and Laurence 2007, 22). Harlow and Laurence (2007, 19-21) discussed age and status indicators in Roman funerary inscriptions. Their findings suggest that less emphasis was placed on chronological age, the older and more secure in status the person to be commemorated was. Leas (2007, 29) hypothesised that it was likely for the majority of the Roman population to have been unaware of their actual age, even though there were annual festivities to mark a person's birthday among the higher social ranks.

Crummy (2010) gave an overview of grave goods in late Roman child burials associated with a protective function. Coins appeared relatively frequently, which, depending on their position within the grave may signify Charon's fee. Figurines of bears were found in five non-adult burials in Britain, three of which were recovered from Roman Colchester, Essex. Interestingly, a total of only nine bear figurines have been found to date from burials in Britain and Germany. Crummy (2010) argued for an interpretation of these as protective charms (Fig. 2.1). Pipe-clay figurines of the *Venus* have also been recovered from child burials in Roman London, perhaps marking particular religious or ritual significance (Fittock 2015). One of these children may have been suffering from rickets (Conheeney 2000, 277-297). Dating to the 2nd century AD, another child inhumation from Arrington in Cambridgeshire was recovered with an array of pipe-clay figurines, including a mother-goddess (Green 1993; Fittock 2015). What is of particular interest about this burial, is that the child was reported with hydrocephalus (Duhig 1993). Another example of an unusual Romano-British child burial comes from the cemetery at Lankhills in Winchester. Clough and Boyle (2010, 70-71) reported a young child around 8 months-2 years old, buried with a rich array of jewellery, including bone bracelets and glass beads. This young child was decapitated with the head placed between the feet, with no skeletal pathology reported.

Figure 2.1. Bear figurines found in a 2nd century child burial from Colchester (from Crummy 2010, 40)

The cremation burial of a young child in Godmanchester, Cambridgeshire, dating to the mid-2nd century AD had been uncovered with three pots, two bangles and bronze and gold box-fittings, alongside clay figurines of a bull and a horse (Going et al. 1997). Going et al. (1997) have suggested either votive functions of the figurines, as symbolic representations of sacrificial victims, or their function as toys. The generous furnishing of the cremation has also been interpreted as a possible display of status. These are similar finds to the ones made in Arrington and Colchester. The Arrington figurines date to the mid-2nd century AD, whereas the figurines in the Colchester 'child grave' date to the mid-1st century AD (Taylor et al. 1993; Eckardt 1999). The Colchester 'child grave' is however problematic. The absence of anthropological evidence prevents concrete interpretations of the finds in light of the age and sex of the individual in the grave, especially since pipe-clay figurines are found with both adults and children (Eckardt 1999; Fittock 2015).

Wells (1968, 41-42) described grave goods found in a child burial to the northwest of the bulk of adult inhumations during excavations in Verulamium Hills Field of St Albans in Hertfordshire. The child was found in a well-constructed grave, in a lead-lined coffin, wrapped in a woollen shroud with a coin placed in the mouth. Also included were 'toys' and other items: a staff or baton, beads and the remnants of the bronze handle attributed to a fan. A phallic amulet was interpreted as a sex indicator (Wells 1968, 42). Finally, the grave contained the vertebra of an ox, possibly food for the afterlife, and two seashells of a species not native to Britain but the Mediterranean and used to make purple dye (Stratton 1968, 42; Wells 1968, 42. Toynbee (1971, 41) provided a similar example of a burial located in a cemetery outside the city of Rome. The grave dated to the mid-2nd century AD contained the remains of a mummified 7-8 year old girl, buried with earrings, a necklace and ring, and an ivory doll and miniature pots, possibly a display of toys. The girl's skeleton showed lesions indicative of metabolic disease and she was believed to have died as a result of rickets (Toynbee 1971, 41). However, there is no substantiation within the publication on how the dietary deficiency and cause of death were diagnosed.

The above examples have demonstrated how studying childhood in the past without an anthropological component is difficult (Kraus 2006, 12-13). The bodies themselves are often treated as secondary to grave furnishings and other artefacts, even though the skeletal evidence can disclose a wealth of information on a diverse range of aspects. Diet, environmental influences and health signatures can manifest skeletally, whereas artefacts can only faintly elude to these concepts (Halcrow and Tayles 2008a). The presence of children within archaeological theory remains partial, with most archaeological research concerned with their burials and material culture rather than an integration of their skeletal evidence. In order to fully appreciate the potential that children offer as an archaeological source, their actual bodies rather than just their burials need to be considered. For Romano-British archaeology especially, a thorough evaluation of non-adult skeletons and their burial evidence within and between sites is lacking. To date, this dearth of evidence prevented a conclusive hypothesis of the nature of infant and child burials and non-adult treatment in both life and death. The study of childhood in Roman Britain is marked by palaeopathological investigations on one end of the spectrum, and interpretation of their graves in social archaeology on the other. Bridging this gap between skeletons and burial treatment may yield valuable new insights into the treatment children received in life and death, and provide a more holistic picture of how ill-health and death of young members of society influenced their burial. This thesis will devote a chapter to the palaeopathology of Romano-British children in relation to burial characteristics, with the intention to reveal health-based rather than age-based patterns in burial.

2.2. POTENTIALS AND LIMITATIONS OF NON-ADULT BIOARCHAEOLOGY

2.2.1. Theoretical issues

A biocultural approach allows data on biology and health to expand on cultural factors acting on the study population during their lifetime (Blakely 1977; Ubelaker 1978, 142). Examination of the skeletal traits and pathologies of the dead are used as a vehicle to elaborate on the lives of the living population. There are, however certain drawbacks to this approach (Halcrow and Tayles 2008a). An archaeological study population is static and closed, as opposed to the open and dynamic living population it originated from (Waldron 1994, 20). One the one hand, palaeopathological observations reflect the health status of a child at death, a particular point in life, whereas stress indicators such as enamel hypoplasia, can also serve as a window into earlier childhood episodes of stress. The social, cultural and physical interactions of an individual with the environment are however fluid and diverse. Pathologies within the skeleton may therefore vary across time and physical as well as cultural space (King and Ulijaszek 1999, 161-176). The absence of pathological conditions on skeletons does not equal a healthy population, and the palaeopathological signatures we observe are those of the non-survivors. A population that shows no signs of skeletal pathologies may signify a particularly unwell cohort who died during the acute stages of a disease before it acted on skeletal tissues. Conversely, skeletal assemblages that exhibit a range of pathologies may have been overall healthier since these individuals acquired disease and lived into its chronic stages involving skeletal changes (Wood et al. 1992). This so-called ‘osteological paradox’ can be overcome by studying multiple indicators of morbidity to represent individual health at death and during life. Lesion frequency must also be considered in light of mortality according to age groups, allowing us to assess age-based patterns of morbidity and mortality within specific cultural contexts (Goodman 1993; Goodman and Martin 2002; Wright and Yoder 2003).

We also have to bear in mind that Wood et al.‘s (1992) and Goodman’s (1993) recommendations for the interpretation of morbidity and mortality in past populations are based on adult individuals. The study of children poses slightly different challenges since this is a population of individuals who failed to live to adulthood, and are therefore non-survivors in a more complex sense. Their informative value can however be much more insightful regarding the adaptive successes of a past population (Lewis 2007, 81). Concerning age-specific mortality, the death rates of infants are particularly helpful in determining how well a population has adapted to its environment and its overall population fitness (Hrdy 1992; Saunders and Barrans 1999). Fertility, and the health of the children serve as a measure of a population’s ability to adjust to a changing environment and sustain itself (Mensforth et al. 1978; Saunders and Barrans 1999, 184).

A further difficulty regarding non-adult skeletons is the rapid bone turnover. Cortical porosity and new bone formation in infancy and early childhood is a product of normal healthy bone growth (Ortner and Turner-Walker 2003, 15; Ortner 2012, 252-254). Lesions in children heal faster than in adults, a period of stress or illness may therefore only leave a temporary trace as it is remodelled soon after the cessation of the adverse condition (Lewis 2007, 133). Similarly, the heightened responsiveness of non-adult skeletons to changing health and living conditions makes them more sensitive to stress and therefore a more reliable indicator of cultural and environmental stressors (Goodman and Armelagos 1989). The palaeopathology of non-adult skeletons has largely been ignored in favour of their graves and ages-at-death that received attention in social archaeology. There is however a wealth of information that can be gathered by studying the biological anthropology and palaeopathology of non-adult skeletons, including fertility rates, child feeding and rearing practices, maternal health and the treatment, care and status a society awarded to children in both life and death (Saunders and Barrans 1999, 199; Lewis 2007, 10-13). Children are particularly sensitive to cultural and social factors promoting disease and general malady, hence their skeletal analysis offers important reference points for our understanding of health and wellbeing in past populations (King and Ulijaszek 1999, 167-168).

The presence of ill individuals within a skeletal sample may also be regarded as a stance of a community's level of care (Tarlow 2000). It is assumed that by supporting ill or physically impaired individuals, populations display moral decency and compassion (Dettwyler 1991; Laes 2013, 137-138). Dettwyler's (1991) consideration was specifically aimed at disability, but parallels can be drawn which apply to individuals of generally poor health and the level of care they received. Skeletal manifestations of physical impairment do not deny the fact that disabled individuals may have cared for themselves, tried to overcome their disability and actively contributed to their society (Roberts and Cox 2003, 12). On the other hand, disabled individuals in the past may have solely survived, rather than being cared for in a manner that we deem decent and compassionate today. It also remains debated whether Western attitudes towards disability, quality of live and motivations behind giving care are adequate for communities in the past (Laes 2011b,c). Considering disabled children in particular, additional processes have to be considered. Rather than being cared for by the community, disabled children would have been cared for (or neglected) by their parents primarily (Southwell-Wright 2014). Given the specific sociocultural context, this may have been either a blessing or a curse. In Rome for example, the physician Soranus stated in his prominent 2nd century AD work *Gynaecology* to inspect the newborn as to whether or not he or she was "worth rearing" (Temkin 1991, 79-80), and the Classical literature suggests that parents could resort to infanticide and exposure of these children without being stigmatised (Grubbs 2013, 88). In Roman Britain, children with congenital conditions, such as hydrocephalus, deafness or probable birth injuries have been recovered where the burial archaeology suggests very deliberate and careful practice (Molleson 1989; Southwell-Wright 2014). These remain case studies still, but demonstrate that disabled children were brought up in Roman Britain, with parents opting against infanticide or exposure. Prone burial has been noted as commonly accompanying both adult and child burials where the palaeopathology suggests a disability (Southwell-Wright 2014). It is therefore of interest to investigate if congenital or developmental conditions in Romano-British children correlate with specific treatment in death.

2.2.2. Issues of preservation

It is necessary to be aware of the many caveats encountered when trying to reconstruct health and disease in non-adults in the past. Skeletal pathology is an indicator of illness within the non-surviving population, but may not reflect the full extent of stress and disease in the living population and is further hampered by post-depositional factors affecting skeletal preservation (Walker et al. 1988; Waldron 1994, 11). These post-depositional factors, acting on non-adult skeletons consist of both extrinsic and intrinsic factors (Fig. 2.2). Extrinsic factors are defined as the burial environment, flora and fauna local to the site and anthropogenic activities in relation to the corpse after death, such as the act of burial (Ubelaker 1997, 77-78; Sorg and Haglund 2002, 11; Bello et al. 2006; Komar and Buikstra 2008, 202; Djuric et al. 2011). Additionally, intrinsic factors such as age, sex, pathological conditions or trauma can act on bone preservation, and therefore representativeness of the dead individuals' biological signatures compared to the living population they originated from (Waldron 1994, 16-20; Manifold 2012). Bello et al. (2006) and Djuric et al. (2011) suggested that non-adult skeletons are affected by intrinsic factors that promote differential preservation, including their smaller size, shape, reduced bone mineral density and less organised bone microstructure. Intrinsic factors such as the bone mineral and water content also differ between the developmental stages of non-adults (Vinz 1970). For example, bone density is higher during the neonatal period than during the second half of the first year of life. Up until about two years of age, infants and young children have lower bone mineral content than neonates (Guy et al. 1997). Acsadi and Nemeskeri (1970) were among the first to argue that the reduced recovery of non-adult skeletons cannot be blamed on these factors alone, as it may be primarily shallow and less careful burials of non-adults that expose the remains more readily to ploughing, erosion and scavenging. Using the prehistoric site at Windover Pond, Stojanowski et al. (2002) evaluated preservation in 110 individuals aged from infancy to old adulthood, and emphasised that skeletal survival was neither sex- nor age-specific but a result of burial location. Vertical depth was identified as the most significant predictor of preservation. The assumption that the absence of child skeletons is a result of preservation and taphonomy alone is not valid (Perry 2006), and taphonomic agents and preservation factors are not uniform between or within sites (Henderson 1987, 43). Bello et al. (2006) mentioned poor preservation of non-adult skeletons as well as funerary exclusion as reasons for underrepresentation in cemetery samples. Hence, it is wrong to assume that the absence of non-adult skeletons is purely due to differential preservation.

The process of excavation itself may result in additional bias, depending on the expertise of the excavator, and collection, recovery and post-excavation objectives (Komar and Buikstra

2008, 203). Not every excavator is trained in the recognition, correct identification and recovery of the very small elements that compose a child skeleton, which makes them likely to be missed or misidentified (Buckberry 2000). Additional, burial outside of the formal cemetery in more shallow graves may simply have been a more ‘convenient’ option to the burying community. Martin-Kilcher (2000, 135) remarked on the possibility of separate areas reserved for infants and older children, especially within or outside of the larger formal cemeteries which may have been missed in past excavations and initiated differential representation of age groups. Ultimately, the quality and quantity of the bones available for study dictates the detail of the osteological data that can be reported, bearing in mind that the assemblage available for study is a reflection of the rate of burial rather than mortality at any given site (Saunders and Hoppa 1993).

Disease/trauma/surgery

Taphonomic processes	***Examples of corresponding mechanisms***
Burial	Inhumation, disposal
Decomposition	Bacteria, moulds, invertebrates
Dispersal	Vertebrates
Chemical action	Soil, water, acidity
Disturbance	Grave cutting, ploughing
Exhumation	Recovery
Post-excavation	Washing, sorting, storage

Osteological analysis

Figure 2.2. Effects on bone survival (from Waldron 1987, 56)

2.2.3. Age and the concept of childhood

The term ‘childhood’ and its associated chronological ages exhibit rather wide-ranging differences in social meanings and definitions awarded across cultures and time (Halcrow and Tayles 2008a). As Perry (2006) pointed out, current Western views on childhood are based on chronological age. In order to render bioarchaeological studies valid however, culturally appropriate age categories need to be applied. There are three distinct approaches to define age from a sociological perspective which are beneficial for bioarchaeological studies (Ginn and Arber 1995). Age comprises of a chronological, social and physiological component (Halcrow and Tayles 2008a). Chronological age is dictated by age in years and may involve a change in social standing as the individual turns older, impacting on privileges, expectations and certain restrictions of behaviour. In contrast, social age is a sociocultural construct, which defines age-appropriate norms in attitude and behaviour. Social age closely links with transitions in the life course and is therefore influenced by gender differences in development. Lastly, physiological age is the product of the body’s functional ability. Growth and levels of stress are influenced by the environment, hence physiological age reflects class, gender and social milieu (Ginn and Arber 1995, 5-10; Redfern and Gowland 2012). The different age components depend on one another, for example the link between chronological and physiological age is easily identified. Social age is more variable and less dependent on both chronological and physiological milestones.

There is a lack of consensus in osteological and social archaeological studies regarding the terminology and use of age categories. As an example, the term ‘infant’ should be used according to its clinical connotation which labels the first 12 months of life, although it remains in use in the osteological literature to describe young children up to the age of five years old (Lewis 2007, 1-2). Older site reports show discrepancies in the terminology and allocation of age categories, the terms ‘child’ or ‘juvenile’ are used interchangeably with no clarification or definition on physiological age given. For example, Bowsher and Barber (2000, 104) used five age categories to describe non-adults from Roman London: 0-1 year, 2-5 years, 6-10 years, 11-15 years and 16-25 years. Prior to the re-assessment of the non-adult assemblage at Poundbury Camp by Lewis (2010), the 1993 report by Farwell and Molleson only contained two categories for non-adults: ‘infant/child’ for all 0-15-year olds and ‘young adult’ for 15-25-year olds.

There is also cultural discrepancy in the definition of live births, foetal death, abortion and stillbirths. Counting and registering infants declared dead before, during or shortly after birth is culturally specific (Saunders and Barrans 1999, 185). The perinatal period is defined as the period from the 28th week of gestation to the 7th day after birth (Shapiro et al. 1968). Some countries consider a neonate dying within the first 24 hours as neither stillborn nor a live birth but an abortion. In other countries, babies dying within the first three postnatal days are registered as stillborn (Saunders and Barrans 1999, 185; WHO 2014). Current Western definitions of stillbirths, live births and foetal deaths may therefore not be entirely relevant for past societies.

An osteological means for distinguishing perinatal from neonatal deaths in archaeological contexts is the neonatal line in the tooth enamel of newborns. For the neonatal line to manifest, a perinate has to survive for at least seven to 10 days to allow formation of a band between the pre- and postnatal tooth enamel (Humphrey et al. 2005; Smith and Avishai 2005). Perinatal tooth crowns are however only sporadically recovered. It is more fruitful to distinguish between those having died around the time of birth up to 40 weeks gestation (neonatal death), and those within weeks after (post-neonatal death), using long bone regressions. Endogenous causes, such as congenital conditions or birth trauma are the main causes for neonatal death, whereas post-neonatal deaths result from environmental, or exogenous, insults (Bourgeois-Pichat 1951; Vögele 1994; Murray and Frenk 2002; Humphrey et al. 2012). This approach therefore allows us to use mortality in newborns as a means to exploring a community's adaptive success and overall population fitness.

There is no established age threshold based on biological maturation at which childhood ends and adulthood commences. Some authors favour a child-adult boundary at 17 years old, others prefer an age of 21 years. In order to ensure continuity for the purpose of this thesis, the age categories and terminology proposed by Lewis (2007, 2) will be followed (Table 2.2).

Table 2.2. Age categories and corresponding terms

Phrase	Age stages
Embryo	First 8 weeks of intra-uterine life
Foetus	8 weeks of intra-uterine life up to birth
Stillbirth	Infant born dead after 28 weeks gestation
Perinate	Around birth (from 24 weeks gestation to 7 days postpartum)
Neonate	Birth to 27 postnatal days
Post-neonatal	Up to 1 postnatal year
Infant	Birth to 1 year
Child	1 to 14 years
Adolescent	14 to 17 years
Non-adult	Any age younger than 17 years
Adult	Any age older than 17 years

(from Lewis 2007, 2)

2.2.4. Sex determination

Biological sex may not equal gender, especially in pre-pubescent individuals (Lewis 2007, 47), and several issues prove the sex determination in immature skeletons difficult. Physical maturation and therefore the expression of sexually dimorphic traits of the pelvis and skull is variable on an individual and population scale, as well as between the sexes (Wilson et al. 2015). It is not until puberty that traits of the skull and pelvis become sexually dimorphic, and only to a limited level. However, there is evidence suggesting that sexually dimorphic areas exist prior to the onset of puberty (Mays 2000, 121). Sexing methods for non-adults are available, albeit with varying accuracy, ranging from just under 70% to over 80% (Saunders 2000, 138-139). Schutkowski (1993) for example, proposed a method for determining sex in infants based on non-metric morphological variation in the ilium and mandible with accuracy ranging from 54-95%. Rogers (1999) proposed sex determination in adolescents using four traits of the posterior distal humerus based on trochlear constriction, trochlear symmetry, olecranon fossa shape and depth, and angle of the medial epicondyle. The method is applicable to non-adult skeletons as soon as the distal humerus has fused, which may commence as soon as 11 years in females and 12 years in males (Scheuer and Black 2004, 274). Testing of the method by Rogers (2009) and Falys et al. (2005) on British and Portuguese documented skeletal assemblages yielded fluctuations in accuracy from 67% to 81%. The error associated with sexing of the distal humerus may be up to 33%, and we have to bear in mind that sex can be guessed correctly with 50% accuracy. As soon as elements of the pelvis and skull have fused, the standard methods for sexing of adult skeletons can be applied, i.e. the Phenice technique for pelvic morphology (Phenice 1969) which is up to 96% accurate (Sutherland and Suchey 1991), or assessing cranial morphology after Walker (1994) in Buikstra and Ubelaker (1994). However, the latter has a 20% error range and cranial traits may be expressed less prominently in young men (Walker et al. 1988; Walrath et al. 2004).

Determining the sex of non-adult individuals is a particularly prominent issue in non-adult bioarchaeology, as being able to identify it correctly and with reliability yields great benefits. Being able to determine sex allows for more accurate age estimation, as methods such as Moorrees et al. (1963a,b) present data for males and females separately. This in turn enables the exploration of morbidity and mortality patterns in boys and girls, revealing sociocultural differences in the treatment of children and sex-specific variables in parental investment (Koziel and Ulijaszek 2001; Lewis 2007, 48). When discussing growth, particularly around the pubescent growth spurt from 10-12 years old, sex-specific differences arise in growth velocity and ultimately attainment of adult stature. Differentiating male from female growth curves in archaeological populations is therefore a powerful exploratory tool in identifying social and environmental factors that influenced adolescents in the past (Lewis et al. 2015). Due to the variability in the accuracy of current non-adult sexing methods, especially in children below the age of six years old, sex determination remains a debated subject (Sutter 2003). Most researchers still refrain from non-adult sexing as more testing of existing methods is required, and accuracy fluctuates depending on the biological age of the individual. Rather than an exploration of gender-based differences in growing up, the current study is an investigation of childhood as a distinct phase in the life course of Roman Britons. The focus of this project is on the analysis of urban versus rural differences in child health according to distinct developmental stages. Although sexing has a number of benefits, the associated error introduces bias when discussing sex-specific patterns, especially when methods prove more reliable for one sex than the other (Sutter 2003). Additionally, there are age groups in which sex can be determined more accurately than in others which would only allow for sex to be considered in the discussion of morbidity and mortality patterns in certain age groups. The problems associated with the sex determination in immature skeletons can be eliminated by treating non-adults and their respective age ranges as demographic groups, albeit with the trade-offs of less accurate age estimation and growth curves.

2.2.5. Growth

Osteoblast, osteoclast and osteocyte activity regulate linear and circumferential bone growth which is affected by genetic and external variants (Ortner 2003, 14; Cameron 2007). An individual's genetic make-up influences height attainment. By discussing averages across populations, these genetic influences can be buffered, which allow for an interpretation of growth as an indicator of health status (Steckel 1995, 1903). Growth patterns may be influenced by factors as wide-ranging as infection, nutrition, urbanisation, socioeconomic status, climate, migration, parasites, altitude, noise, lead exposure, physical activity patterns and biological stress (Bogin 1999; Cameron 2007). Especially linear growth is frequently interpreted as a sensitive indicator of health within a population (Saunders and Hoppa 1993; King and Ulijaszek 1999, 161). Assessing and discussing growth profiles in archaeological populations provides an overview of growth-related change and indicates how satisfactory growth is within a given population. The health of the community as a whole can be gauged, as well as the effectiveness of a population to adapt to a changing environment (King and Ulijaszek 1999, 161; Goodman and Martin 2002, 20-21). The effect of early growth retardation or stunting can be compensated for by catch-up growth once the adverse condition has resolved (Tanner 1981; Cameron et al. 2005; Vercelotti et al. 2014). Although some catch up growth can also occur as general systemic response (Johnston and MacVean 1995). When growth retardation or stunting is observed, it is vital to bear in mind that shorter stature and smaller body size are adaptive in certain adverse conditions. Short adult stature should be interpreted as side effect of morbidity with its extent dependent on the particular diseases affecting the population. The aetiology behind stunting and growth retardation may therefore not always be the same (Saunders and Hoppa 1993).

In contrast to modern longitudinal growth studies which measure children at regular intervals throughout their development, archaeological growth data from non-adult skeletons is cross-sectional, stemming from a cohort of non-survivors measured at one point in time, i.e. death, before attaining full adult height (Saunders 2008, 133). Those non-surviving children may have experienced greater levels of stress and elevated morbidity within their respective age categories through chronic illness, which potentially yield comparatively smaller stature than in the surviving cohort (Saunders and Hoppa, 1993). However, these children may have also died as a result of acute illness or fatal accidents, which would not have affected their growth prior to death (Lewis et al. 2015). A further caution in archaeological growth studies in comparison to their present-day equivalents is their often smaller sample size spanning a longer time period, as burial grounds may be in use for several hundred years (Humphrey 2000). The earlier maturation in females and longer elevated growth velocity of males during the pubertal growth spurt introduce bias when discussing growth in unsexed non-adults (Saunders and Hoppa 1993; Humphrey 1998; Visser 1998). Archaeological growth data may be further skewed due to the error ranges encountered in skeletal and dental ageing (Humphrey 2000; Lewis 2000; Saunders 2008, 134). Dental ageing as the most precise methods may still produce a two-year error range (Lampl and Johnston 1996). This provides a rather bleak outlook since dental development is less influenced by the environment than skeletal maturation and ageing methods based on tooth eruption and formation are generally considered more reliable than skeletal milestones (Cardoso 2007). Awareness of the ageing techniques used is therefore vital when comparing archaeological growth curves. Roksandic and Armstrong (2011) suggested the use of life stages rather than set ages in growth studies and palaeodemography to buffer against the error ranges introduced by ageing. Additional means to aiding in more meaningful interpretations of growth profiles in past non-adult populations, is their palaeopathology. Knowing how these children were affected by specific health hazards, such as malnutrition, will allow us to make more holistic inferences about growth (Pinhasi 2008).

2.2.6. Non-adult palaeopathology

Palaeopathological analysis of non-adult remains encompasses the observation of skeletal lesions indicative of ill-health and disease. Macro- and microscopic methods are complemented by isotope analysis, ancient DNA (aDNA) analysis, and radiography. The latter is non-destructive and relatively cost-efficient, with most institutions having radiography equipment to aid in the study of skeletal remains. Radiography can be used in dental ageing of non-adult individuals, and most importantly in the investigation of specific skeletal lesions. Tooth formation in the alveolar bone is visualised, and skeletal changes that cannot be viewed on the external bone surface can be observed (Ortner 2003, 60). Due to the costly nature of aDNA analysis, it is only rarely used. Stable isotope analysis is mainly concerned with the investigation of diet which may provide information on status, breastfeeding and weaning, as well as migratory patterns (Halcrow and Tayles 2008a). However, it is destructive and relatively expensive, which still makes it a relatively underutilised tool in the study of Romano-British non-adult skeletons.

Saunders and Barrans (1999, 197) pointed out how modern day observations on child health can be constructive when cautiously applied to archaeological populations. Child morbidity and mortality in developing countries can offer valuable insight into possible realities in the pre-industrial past. At present, acute respiratory and gastrointestinal infections in developing countries mark the main cause of death in children (Scrimshaw et al. 1968). It is important to be aware of the dynamics between inadequate nutrition and the risk of infectious disease as both factors may correlate and promote the incidence and severity of the other (Scrimshaw and SanGiovanni 1997; King and Ulijaszek 1999, 165-166; Pinhasi 2008, 364). Pathological conditions that manifest skeletally comprise of trauma, congenital anomalies, circulatory disorders, haematological disorders, skeletal dysplasias, neoplastic conditions, dental disease, or joint, metabolic or infectious diseases. For a certain condition to affect bone, the normal or healthy remodelling balance has to be disturbed, ultimately resulting in either excessive bone formation or loss (Waldron 2009, 19). The observed lesions can either be specific with known aetiology or non-specific with unknown or ambiguous aetiology (Lewis and Roberts 1997; Pinhasi 2008, 363). Sub-periosteal new bone formation, for example, is a pathological lesion observed with a range of adverse health conditions, such as infections, nutritional deficiencies or trauma, but also appears in infants as regular healthy bone growth (Shopfner 1966; Weston 2008, 2012).

2.2.6.1. Enamel hypoplasia

Two sets of teeth are developed throughout the human lifespan. A set of deciduous teeth erupts in early childhood until around two years of age. The deciduous dentition is then gradually replaced by permanent teeth, the last of which may erupt during the early twenties (Hillson 1996, 6). The formation of deciduous teeth commences at around six weeks gestation, with deciduous tooth crowns fully formed within the first year of life (Hillson 1996, 121-124; Scheuer and Black 2004, 149). Permanent tooth crowns start to form just before birth until the age of around 12 years for the third molars (Moorrees et al. 1963a). The pattern of tooth formation and eruption is a useful tool for estimating non-adult age as the sequence is less affected by external stressors than skeletal development (Gaur and Kumar 2012). The dental hard tissues comprise of enamel, cementum and dentine (Fig. 2.3).

Enamel is highly mineralised with a composition that is similar to hydroxyapatite. Enamel is formed by ameloblasts and microscopically arranged in prisms or thin rods (Hillson 1996, 148-149). Dentine also consists of mainly hydroxyapatite but with a higher proportion of organic matter, i.e. collagen, than enamel. It is formed by odontoblasts which share a similar function to osteoblasts in bone (Hillson 1996, 182; White and Folkens 2005, 130; Mays 2010, 11). Cementum is the most bone-like of the three dental hard tissues, and its primary function is to secure the root of the tooth to the periodontal ligament in the alveolar bone. The joint formed by the tooth and socket in the jaw is immobile, the lining by the fibres of the periodontal ligament however acts as an, albeit very minimised, shock absorber (Hillson 1996, 198-199; Schwartz 2007, 181; Mays 2010, 13).

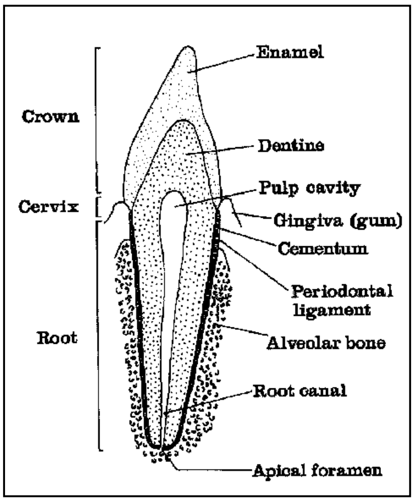


Figure 2.3. Structure of a tooth (from Mays 2010, 13)

Permanent and deciduous teeth provide a permanent retrospective record of early childhood stress by showing linear bands or pits in the tooth crown enamel, granted they are not lost during the time the individual was alive (Hillson 1993, 165). Unlike skeletal tissues, teeth cannot remodel, making enamel hypoplastic defects a lasting witness of stress and illness during childhood. However, if hard and abrasive foods are consumed in the diet, enamel can be worn away over time, obliterating any enamel hypoplasia. Thinning in enamel thickness stems from decreased ameloblast deposition during enamel formation, mainly affecting the anterior permanent dentition, the crowns of which are formed up until four years of age (Moorrees et al. 1963a; Goodman and Rose 1990; 1991; Hillson and Bond 1997; Goodman and Song 1999). The stressors that negatively affect ameloblast secretion are wide-ranging, including trauma, mal- or undernutrition, and infection (Goodman and Rose 1990; 1991; Roberts and Manchester 2010, 75). Several hypoplastic lesions on the same tooth indicate a prolonged or reoccurring bout of illness, malnutrition or stress. The timing of the onset and length of a period of stress may be discerned from the type of teeth affected, such as incisors and canines in the anterior dentition, or premolars and molars in the posterior dentition. The position of the defect on the tooth crown also provides an observable timeframe for the stress episode (Smith 1991; Goodman and Song 1999; Reid and Dean 2000). Enamel hypoplasia can not only occur on the crowns of the permanent dentition that is formed during early childhood but also the deciduous teeth, mostly affecting the canines as a circular defect on the labial aspect (Lukacs 1991). In-utero stress can prompt the formation of these defects, therefore not only informing on the baby's health during the final gestational months but also the mother's constitution during pregnancy (Halcrow and Tayles 2008b). Maternal stress manifested as circular enamel defects on the deciduous canine has been associated with both premature births and low birth weight (Seow 1997; Aine et al. 2000). Inadequacy in the maternal diet may cause osteopenia in the neonate. Normal motor development in the infant then causes trauma to the cortical bone around the area of the deciduous canine crypt due to weakened bone structure (Skinner and Hung 1989; Skinner and Newell 2000). The aetiology of deciduous enamel defects, particularly within the canine teeth, therefore encompasses several factors: maternal ill-health, stress or compromised nutritional status, and ill-health in the infant, either in utero or the neonatal period, and minor trauma which is mainly unintentional and part of a healthy attainment of motor skills (Halcrow and Tayles 2008b).

2.2.6.2. Infectious disease

The prevalence and spread of infectious disease is influenced by various factors such as an individual's age, sex, genetic make-up, nutritional status and immune response, whilst also depending on sanitation and climate. The synergistic relationship between poverty, poor diet and a depressed immune system may lead to greater risk of infection (Scrimshaw et al. 1968; Scrimshaw and SanGiovanni 1997; Dewey and Mayers 2011; Tanner 2014). The susceptibility of a population to infectious disease is a vehicle in exploring social diversity and inequalities. New pathogen exposure via travel, migration, trade and unfamiliar anthropogenic changes to the environment, such as the emerging extensive urbanism in the Roman period, also increase the likelihood and spread of infections (Roberts and Manchester 2010, 165). Bony changes are distinguished as an inflammatory response of the periosteum (periostitis/sub-periosteal new bone formation), cortex (osteitis/sclerosing osteomyelitis), or medullary cavity (osteomyelitis) (Ragsdale et al. 1981; Resnick 2002, 2378-2379; Ortner 2003, 181). Several causes are associated with these lesions, including fungi, parasites, viruses and the staphylococcus, streptococcus and pneumococcus bacilli (Nelson 1990; Goodman and Martin 2002; Roberts and Manchester 2010, 168). A number of patterns in lesion distribution are specific to tuberculosis, treponemal disease and leprosy.

2.2.6.2.1. Endocranial lesions

Non-specific lesions may manifest on the inner table of the cranial vault. Lewis and Roberts (1997) and Lewis (2007, 141) described these as areas of reactive new bone formation on the occipital, parietal and frontal bones. Pitted and grooved lesions resembling vascular depressions, hair-on-end formations or worm-like deposits are commonly observed. Inflammation secondary to infection has been suggested as a causative agent, alongside other possible aetiologies of trauma, syphilis, vitamin A, C or D deficiency, tumours, tuberculosis and meningitis (Schultz 2003, 93; Lewis 2004). The only type of endocranial lesions with specific aetiology are granular in appearance, similar to arachnoid fovea in adult crania, indicative of tuberculosis (Schultz 2003, 94-95).

The endocranial patterns of the rapidly growing skull within the first two years of life may be difficult to distinguish from those owing to an inflammatory response. Endocranial lesions in very young children, particularly on the occipital bone, may therefore not have a pathological origin (Lewis 2004). Mitchell (2006) challenged this reasoning and attested that all, what he termed 'intracranial lesions', on the occipital bone of those under 2-years old, are a pathological response. The main argument for a pathological cause is the distribution of lesions, as healthy growth should stimulate a similar response of new bone formation on not just the occipital bone in isolation but other elements of the cranium. When children suffering from infection or trauma are placed in their backs for prolonged periods, occipital lesions could form as a result of pooling of blood or pus at the back of the skull. Recent work by Zahareas (2011) supported the conclusions on the aetiology of endocranial lesions by Lewis (2004), suggesting that endocranial lesions relate to healthy growth and development as well as pathological causes. Differential diagnosis and taking the overall health status of the individual into account enables the most informed conclusion on the underlying cause of endocranial lesions in individual cases.

2.2.6.2.2. Non-specific infection: periostitis, osteitis and osteomyelitis

Proliferative periosteal reaction is a non-specific inflammation of cortical bone tissue (Fig. 2.4). This type of new bone formation is not solely limited to infection (Ragsdale et al. 1981; Ortner 2003, 196; Weston 2008; Rana et al. 2009). According to Weston (2008; 2012) the causes include trauma, circulatory disorders, joint disease, haematological disease, skeletal dysplasia, and infectious, metabolic or neoplastic disease. Throughout life, the periosteal osteoblasts remain active. As a result, the periosteum may react to a variety of insults by depositing new abnormal bone (Wenaden et al. 2005; Chen et al. 2012). The surface of the affected bone exhibits irregular, poorly organised porous woven bone formation, which tends to be uneven in thickness and distribution. In chronic conditions, or as the bone heals after the insult, the newly deposited woven bone is remodelled into smooth lamellar bone (Ortner 2008, 196-198). The characteristics of the deposited bone (woven/lamellar) therefore indicate the active or healing stages of the underlying pathology.

Lewis and Roberts (1997) have pointed out the difficulties in identifying and interpreting sub-periosteal new bone formation in non-adult skeletons, as regular bone growth in infants between the ages of 2-5 months is at particular risk of being mistaken for a periosteal reaction (Gleser 1949). Radiographic studies revealed that sub-periosteal new bone deposits are a common finding on the long bones of infants, particularly under six months old (Shopfner 1966; Kwon et al. 2002; Rana et al. 2002). Additionally, the more widespread the sub-periosteal new bone deposits, the more difficult it is to discern periostitis from rapid growth (Lewis and Roberts 1997). Another factor to be aware of is the inconsistency in the prevalence of periostitis across population and time periods, which can interfere with its diagnosis (Roberts and Manchester 2010, 173). Due to the varied aetiology of sub-periosteal new bone formation, it is vital to consider the age of the individual and take all bony changes in the skeleton into account, in order to avoid over-diagnosing ‘non-specific infection’ (Mann and Murphy 1990; Ribot and Roberts 1996; Lewis and Roberts 1997; Lewis 2007, 135; Weston 2008; 2012).

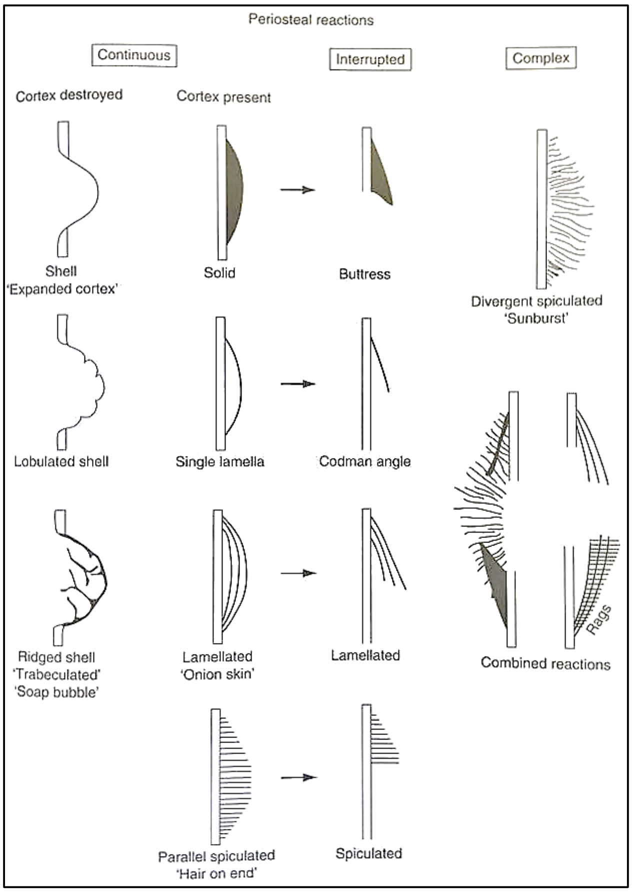


Figure 2.4. Illustration of the types of periosteal new bone formation (various aetiologies, including neoplastic; from Weston 2012, 497 and after Ragsdale et al. 1981)

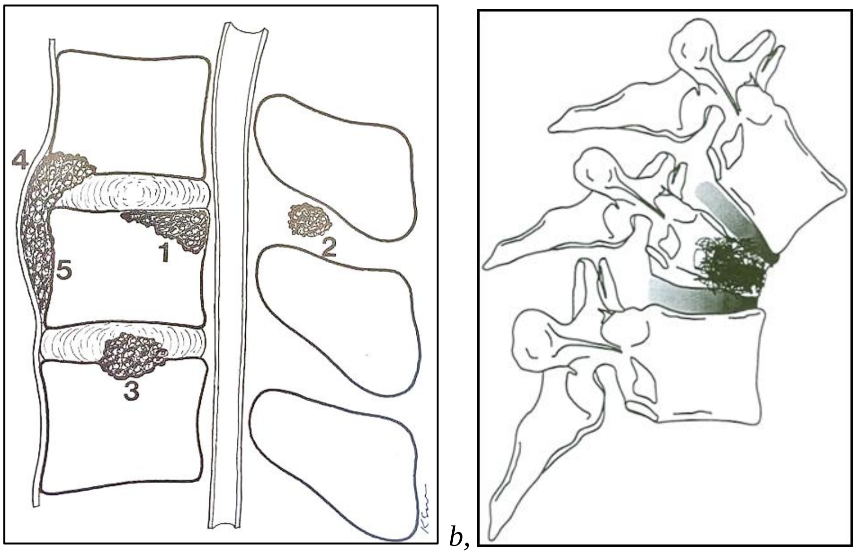
Osteitis and osteomyelitis are additional skeletal responses to infection. Osteitis, or non-suppurative osteomyelitis, is an inflammatory response in the cortex of the bone, whereas osteomyelitis affects the medullary cavity. The latter condition causes necrosis of the bone. Part of the necrotic bone is surrounded by living bone, and these islands of bone necrosis are termed sequestrum. The periosteum reacts to the underlying infection by depositing new bone, the involucrum, surrounding the sequestrum. Cloacae may form in the involucrum, allowing drainage of the abscess in the medullary cavity (Resnick 2002, 2379; Ortner 2003, 181-184). In children, the rapidly growing skeleton generally exhibits a greater blood supply than in adults, especially around the epiphyseal plates of long bones. This causes a much faster and widespread haematogenous dissemination of bacteria and therefore foci for osteomyelitis (Nelson 1990; Resnick 2002, 2378-2379). Weaker and less abundant Sharpey's fibres in children further promote the spread of infection, as the periosteum is less tightly bound to the underlying bone and can be stripped off more easily (Shapiro 2001; Lewis 2007, 138). The hypertrophy of localised infections is therefore more extensive, whilst the risk for more widespread foci is elevated. Although the hypertrophy in children with osteomyelitis may be vaster than in adults, it may also manifest as the opposite which can make a diagnosis of osteomyelitis in dry bone more challenging. The porosity in immature skeleton can prevent the formation of cloaca and an involucrum as pus can drain through the porous bone without prompting other bony changes (Turlington 1970).

2.2.6.2.3. Tuberculosis

Tuberculosis is a chronic infectious disease, which affects the lungs, skin, lymph nodes, the intestines and in rare extreme cases the bones and joints (Roberts and Manchester 2010, 187). The bacterial genus specific to humans *Mycobacterium tuberculosis* is mainly spread via inhalation of airborne droplets but can also spread to the foetus from the infected mother (Lewis 2007, 146; Marais 2011). Its animal equivalent bacillus, *Mycobacterium bovis*, which is mainly found in cattle, can be transmitted by eating or drinking infected animal products (Stead 2000; Grange 2001). Following an initial infection of the lungs, tuberculosis can spread to surrounding tissues via lymphatic or haematogenous flow (Teo and Peh 2004; Marais 2011). *M. tuberculosis* can also spread to the meninges during primary infection in young children. This may cause blindness, deafness and mental retardation, which poses a particular threat for young children under four years old as they make up 80% of tuberculous meningitis cases (Lewis 2004; Nelson and Wells 2004; Walls and Shingadia 2004).

Tuberculosis is frequently depicted as a disease of malnutrition, poverty and overcrowding. The bacillus can survive outside the body in exhaled droplets, sputum or excrement, and those coming into contact with these vehicles are at risk of infection (Nelson and Wells 2004; Teo and Peh 2004; Swaminathan and Rekha 2010; Marais 2011). Detecting skeletal evidence for tuberculosis is therefore a valuable indicator of living conditions. Childhood cases of tuberculosis are of particular interest as they mirror the rate and extent of ongoing transmission of the disease within a population (Nelson and Wells 2004). Tuberculosis is usually contracted during childhood and this primary infection may result in death. It may take between 1-6 months for asymptomatic tuberculosis infection to progress into symptomatic disease (Walls and Shingadia 2004). The rapid progression of infection to disease is unique to childhood tuberculosis (Swaminathan and Rekha 2010). Although the disease may not be evident, a carrier can still infect other people, childhood tuberculosis especially marks an important disease burden as a pool for infection in adults (Nelson and Wells 2004). Secondary infection occurs by repeated exposure to the bacillus or immune suppression, when the latent infection is reactivated. This secondary infection yields skeletal changes (Roberts and Manchester 2010, 187). Only a very small percentage (numbers range from 1-2% to 3-5%) of those with active tuberculosis will show skeletal involvement (Resnick 2002, 2524; Teo and Peh 2004; Swaminathan and Rekha 2010). However, infections sustained by *M. bovis* are 10 times more likely to produce bony changes (Stead 2000). Palaeopathological lesions are marked by osteoporosis of the infected joint, necrosis and reduced bone formation, mainly affecting the spine, hip and knee joints (Lewis 2007, 147; 2011).

Roberts et al. (1998) suggested that periosteal inflammation of the ribs on the pleural aspect may be indicative of tuberculosis. Pfeiffer (1991) suggested three types of rib lesions on the pleural aspects, including plaque formation, expansive and resorptive lesions. The latter may be associated with tuberculosis, whereas plaque and expansion are more likely to be a result of non-specific inflammatory periostitis, which can be linked to a pulmonary infection as well as tuberculosis. Dactylitis is also frequently diagnosed with the infection (Ritz et al. 2011). However, Pott's disease (tuberculous spondylitis), involving spinal collapse and ankylosis, is pathognomonic of tuberculosis (Pfeiffer 1984) (Fig. 2.5). Today, spinal tuberculosis only affects 1% of all tuberculosis patients (Turgut 2001), however in those with skeletal tuberculosis, spinal involvement is observed in 25-60% of cases (Resnick and Kransdorf 2005, 758). Spinal collapse results from abscess growth within the vertebral body initiated by the haematogenous spread of the tuberculous bacilli. The infectious foci may subsequently spread via the intervertebral discs and anterior spinal ligament, eventually leading to an abscess in the psoas muscle, which may eventually spread to the pelvic area. The vertebral abscess, often coupled with infarction and necrosis of the vertebral body leads to a weakened trabecular structure. Ultimately, the vertebral body will not be able to support the weight of the trunk anymore and collapse anteriorly (Resnick 2002, 2527-2535; Ortner 2003, 231-232; Resnick and Kransdorf 2005, 758-761).



a, b,

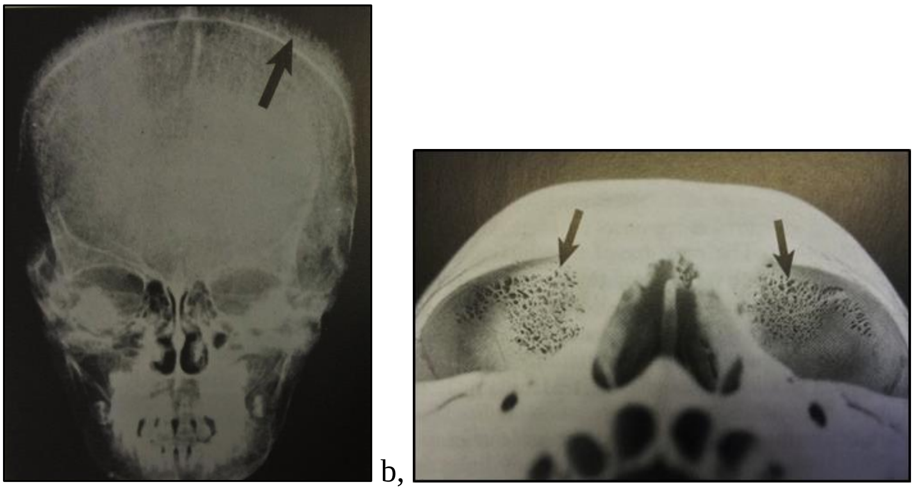
Figure 2.5. Tuberculous spondylitis. a, Areas of lesion development: 1, within vertebral body; 2, in posterior osseous or ligamentous structures; 3, intervertebral discs; 4, prevertebral tissues; 5, subligamentous spread (from Resnick and Kransdorf 2005, 759). b, Mechanism of spinal collapse in Pott's disease (from Aufderheide and Rodriguez-Martin 1998, 123)

Brucellosis is a chronic lung disease prompting spinal lesions, which needs to be considered in differential diagnosis (Ortner 2003, 216). This zoonotic infection by the bacterial genus *Brucella* yields spinal lesions and degeneration of the hip and knee joints in around 10% of those infected (Roberts and Manchester 2010, 216). The infection is contracted from an animal host (*Brucellosis suis* for pig, *Brocellosis melitensis* for sheep/goat and *Brucellosis abortus* for cattle/horse) and spreads to humans via droplet inhalation, contamination of the skin or the ingestion of animal products (Wilkinson 1993, 625). Spinal lesions are characterised by destruction of the vertebral bodies and discs, with reactive sclerosis and sometimes osteophytes which resemble a parrot-beak radiologically (Resnick and Kransdorf 2005, 756-757). Destruction of the antero-superior margin of the vertebral body is counteracted by an increase in the trabecular bone, which is pathognomonic for the disease (Mohan et al. 1990; Ortner 2003, 216). Although brucellosis may be expected in Romano-British skeletal materials due to the extensive exploitation of domesticated animals (Roberts and Manchester 2010, 216), there is a tendency for the disease to affect individuals between the ages of 15 to 35 years (Aufderheide and Rodriguez-Martin 1998, 194). Radiographs are recommended for a distinction between tuberculosis and brucellosis in skeletal materials (Mays 2007).

2.2.6.3. Metabolic disease and nutritional stress

2.2.6.3.1. Cribra orbitalia and porotic hyperostosis

Angel (1966) was the first to describe porotic hyperostosis in the palaeopathological literature as pitting and porosity on the ectocranial surface due to expansion of the diploë, causing the outer table of the skull to resorb. Similar skeletal changes occur more frequently on the orbital roof, referred to as cribra orbitalia by Welcker in 1888. Porotic hyperostosis and cribra orbitalia can range from small porosities to the exposure of large interconnecting trabeculae (Stuart-Macdam 1987). In severe lesions, the trabeculae will be visible as the characteristic appearance of 'hair-on-end' (Stuart-Macadam 1989a, 1992; Lewis and Roberts 1997) (Fig. 2.6). Non-adults have a reduced capacity to sustain higher red blood cell production, yielding hyperplasia of the diploë. Hence non-adult skeletons exhibit active porotic lesions more frequently than adult skeletons which show a higher incidence of healing (Stuart-Macadam 1985; Walker et al. 2009).



a, b,

Figure 2.6. Porotic hyperostosis cranial and orbital lesions. a,'Hair-on-end' on a skull radiograph (Calvin Wells Photographic Collection; from Roberts and Manchester 2010, 230); b, bilateral cribra orbitalia (National Museum of Natural History; from Roberts and Manchester 2010, 231)

It has been assumed that hypertrophic marrow expansion is due to iron deficiency anaemia, a shortfall in iron stores as a result of blood loss, dietary insufficiency, parasitic infection or diarrheal disease (Angel 1966; Lallo et al. 1977; Mensforth et al. 1978; Stuart-Macadam 1985; 1987; 1989a; Holland and O'Brien 1997). However, the relationship between cribra orbitalia, porotic hyperostosis and iron-deficiency anaemia has been increasingly questioned and might not be as straight forward (Wapler et al. 2004; Djuric et al. 2008; McIlvaine 2013). Rather than sharing a common aetiology, cribra orbitalia and porotic hyperostosis may arise from different causes. The lesions may affect an individual simultaneously but diagnosing one condition does not dictate the presence of the other (Walker et al. 2009).

Recent research by Walker et al. (2009) demonstrated that iron-deficiency anaemia alone does not constitute a condition severe enough to sustain the elevation in red blood cell production that causes the bone marrow to expand and lead to cribra orbitalia and porotic hyperostosis (Fig. 2.7). The expansion of the diploë is a result of overproduction of red blood cells, compensating for the accelerated loss of red blood cells rather than a restricted red blood cell production characteristic of iron-deficiency anaemia. Haemolytic and megaloblastic anaemias cause rapid and excessive red blood cell production and prompt extension of the diploë. These may therefore be more apparent causes for hyperostotic lesions. Sickle-cell anaemia and thalassaemia are hereditary haemolytic anaemias that trigger extensive red blood cell production. Megaloblastic anaemia is an effect of vitamin B12 and B9 deficiencies, leading to elevated red blood cell production and therefore hypertrophic marrow expansion. Megaloblastic anaemia due to vitamin B12/B9 deficiency is almost asymptomatic in adults. In children however, bony responses to increase red blood cell production can be observed within months of vitamin B12/B9 deficiency. Walker et al.’s (2009) hypothesis on discounting iron-deficiency anaemia for marrow hyperplasia has since been challenged. Oxenham and Cavill (2010) argued that iron-deficiency anaemia is still a probable cause for hyperplastic lesions since the erythropoeitic activity is increased yet ineffective and confined to the intra-medullary cavity. More recently, it has been suggested that iron deficiency and vitamin B12 deficiency often co-occur, ultimately inhibiting marrow hypertrophy and preventing skeletal changes, as iron deficiency counteracts the elevated erythropoiesis induced by vitamin B12 deficiency (McIlvaine 2013). The opposing views in these papers underline the difficulty in assigning an explicit aetiology to cribra orbitalia and porotic hyperostosis. Decisively, it is important to bear in mind that deficiencies and compromised immune responses often coexist in the same individual and may trigger similar osseous changes, potentially as an adaptive response (Stuart-Macadam 1989b; 1991; 1992).

Cribra orbitalia has also been linked to vitamin C deficiency (Fig. 2.7). Subperiosteal bleeding due to weakened connective tissue can lead to porous and highly vascular new bone formation on the orbital roof (Ortner and Ericksen 1997; Brickley and Ives 2006). Subperiosteal haematomas are more common in children as the periosteum is not as firmly attached. Coupled with weakened Sharpey’s fibres, bleeding will occur. Porosity and new bone formation on the ectocranial surface may also result from scurvy-induced haematomas or an inflammatory response of the periosteum (Walker et al. 2009). Additionally, pitting and porosity on the orbital roof and ectocranial surface due to sub-periosteal new bone formation and remodelling have also been observed in rachitic non-adults (Ortner and Mays 1998; Ortner 2003, 394). It is therefore pivotal to distinguish between hypertrophic marrow expansion and new bone formation, taking skeletal changes throughout the skeleton into account.

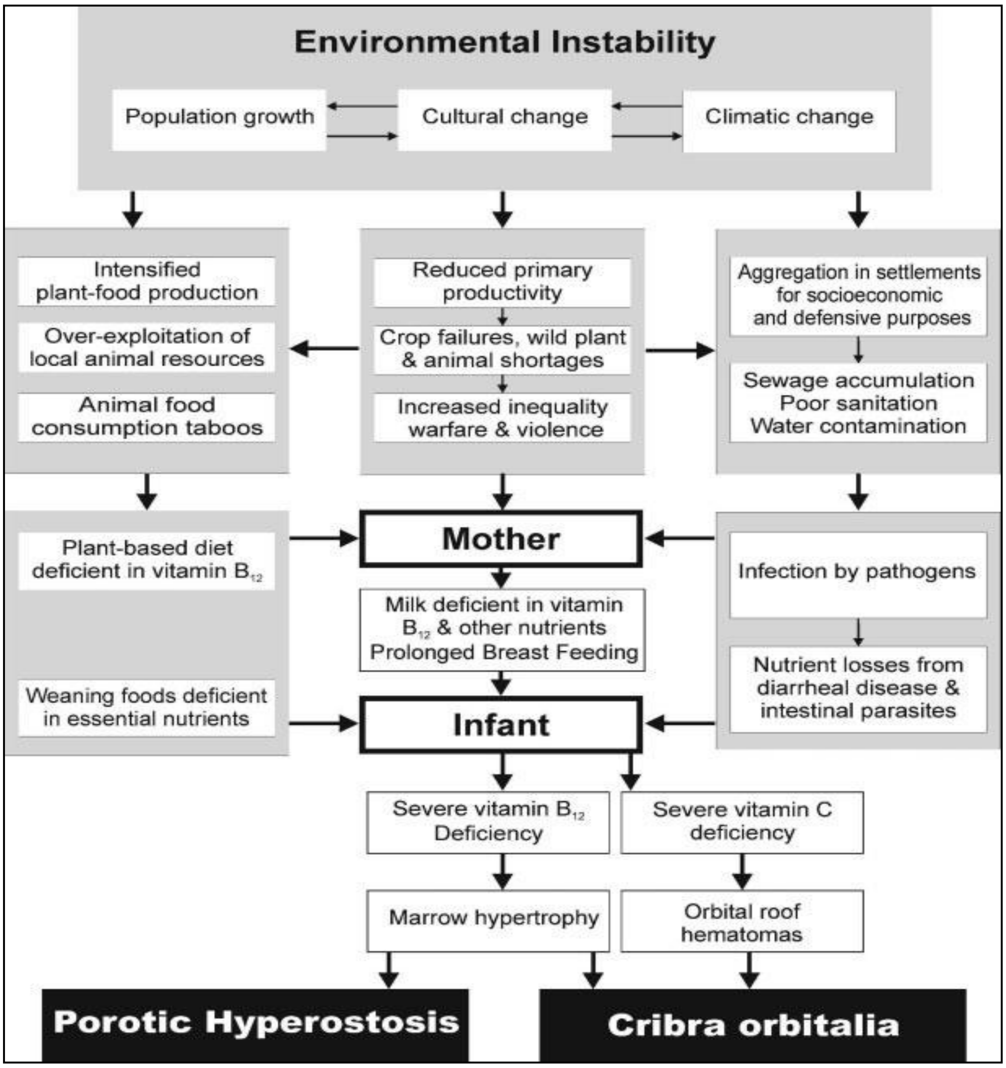


Figure 2.7. Flowchart visualising the complexity of the aetiologies of cribra orbitalia and porotic hyperostosis (from Walker et al. 2009, 113)

2.2.6.3.2. Vitamin D deficiency (rickets/osteomalacia)

Prolonged deficiency of vitamin D will result in rickets and osteomalacia. Rickets affects the development of the growth plates, whereas osteomalacia refers to inadequate mineralisation of trabecular and cortical bone (Pitt 1995, 1885; Pettifor 2003). Vitamin D, a prohormone, is required for the adequate mineralisation of bone formed from endochondral ossification. Calcium and phosphorus are essential for the mineralisation of both osteoid and cartilage, their absorption however is dependent on levels of the vitamin D metabolite 25-hydroxyvitamin D (Holick 2006). Vitamin D is either absorbed via the intestine or formed by the skin's dermal cells in response to ultraviolet light. Vitamin D can be found in oily fish and animal fats, however the skin produces 90% of the body's requirements (Pettifor and Daniels 1997). In growing non-adults, especially infants, chronic vitamin D deficiency will have its most marked impact (Pettifor and Daniels 1997; Mays et al. 2006). The unmineralised bone is porous in appearance and when mechanical forces are applied, bending deformities occur (Pettifor 2003). In severe cases, pathological fractures at the metaphyses of long bones may be present, alongside pseudofractures (Looser's zones) at sites of stress (Pettifor and Daniels 1997; Pettifor 2003). Rickets can occur on a spectrum of vitamin D and calcium deficiency (Thacher et al. 2006; Pettifor 2014) (Fig. 2.8). For example, inadequate weaning foods and breastfeeding by a chronically deficient mother will not meet a child's required calcium levels (Pettifor 2004; Shin et al. 2010). Aetiologically, rickets can therefore not only point towards a lack of exposure to sunlight and associated cultural practices or calcium deficiency, but also female health, and patterns in transitional feeding.

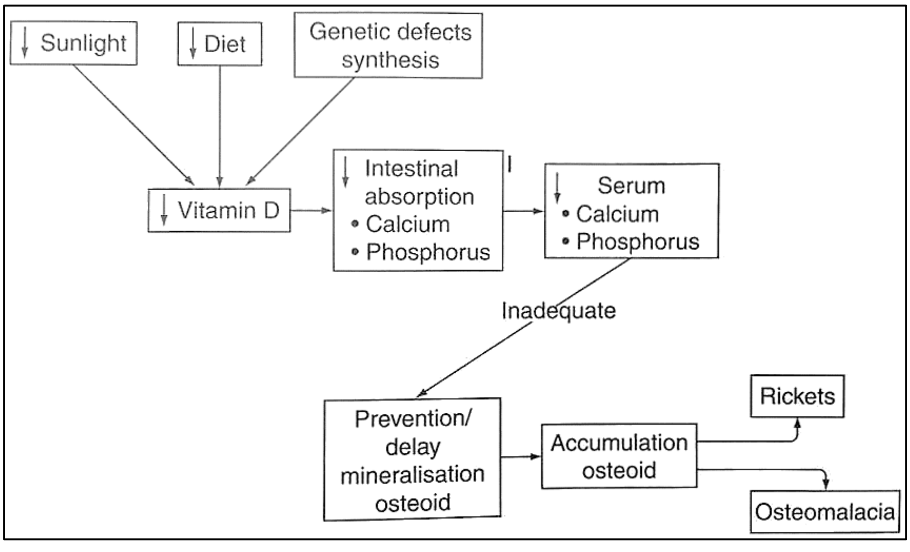


Figure 2.8. Flow diagram of vitamin D attainment and rickets (from Brickley and Ives 2008, 76)

2.2.6.3.3. Vitamin C deficiency (scurvy)

Vitamin C deficiency will result in the clinical condition of scurvy. Ascorbic acid, preformed vitamin C, needs to be ingested and absorbed since humans, unlike most mammals, are unable to produce vitamin C independently (Brickley and Ives 2008, 41). Collagen and osteoid synthesis is compromised in scorbutic individuals, skeletal growth is slowed down and sub-periosteal haematomas occur at the weakened walls of small blood vessels. Lesions ascribed to vitamin C deficiency are characterised by a localised increase in bone porosity and periosteal new bone formation at the site of haemorrhaging (Ortner and Ericksen 1997; Brickley and Ives 2006). Non-adult skeletons, especially those of infants and young children are more likely to exhibit scorbutic lesions due to rapid growth (Mays 2008, 223). Even a very minimal intake of ascorbic acid can prevent clinically significant symptoms, which can improve within two weeks of administering high doses of vitamin C (Cheung et al. 2003; Pimentel 2003). Apart from direct evidence for a lack of fresh fruits and vegetables in the diet, scurvy within a population can relate to wider implications of diet regarding economic structures and social hierarchies, ecology and behaviour, resource stress, and maternal health (Armelagos et al. 2014; Buckley et al. 2014; Crandall 2014; Crandall and Klaus 2014; Halcrow et al. 2014; Stark 2014)

2.2.6.3.4. Acquired anaemia

Iron deficiency anaemia, the most common form of anaemia, is characterised by a decrease in red blood cell production, as iron is needed for the synthesis of haemoglobin (Ustundag 2011). The lifespan of red blood cells in an anaemic individual is shortened, and the transmission of oxygen to the body cells is compromised (Stuart-Macadam 1989b). Cribra orbitalia and porotic hyperostosis have been linked to childhood iron deficiency anaemia (Stuart-Macadam 1985; Oxenham and Cavill 2010; McIlvaine 2013), but may also result from general nutritional deficiencies, infectious disease, or genetic anaemias (Keenleyside and Panayotova 2006; Brickley and Ives 2008; Walker et al. 2009). Modern clinical studies show that depleted iron stores in the mother during pregnancy and lactation may lead to iron deficiency anaemia and low birth weight in the infant (Ribot et al. 2013). Dietary iron is available from cereals and red meat, and deficiency may result from a variety of causes including chronic blood loss, parasites, an increased pathogen load, under- or malnutrition (Stuart-Macadam 1985; 1992; Holland and O'Brien 1997; Lewis and Roberts 1997). Holland and O'Brien (1997) attested that a cereal-based subsistence correlates with iron deficiency due to the uptake of phytates which interfere with iron absorption in the intestine. In cases of malnutrition, anaemia may occur alongside rickets and scurvy (Stuart-Macadam 1989b; Pettifor 2003).

Dietary stress may not only comprise of deficiencies from under- or malnutrition but also overexposure to and ingestion of harmful substances. Lead intake has a variety of adverse health effects and may result in anaemia, as well as sharing a synergistic relationship with iron-deficiency anaemia (Aufderheide and Rodriguez-Martin 1998, 318; Kwong et al. 2004; Roberts and Manchester 2010, 153). Once ingested or absorbed via the skin, lead accumulates in the bone mineral hydroxyapatite. Bone homeostasis and remodelling will gradually release lead into the bloodstream whilst also storing it in skeletal tissue. When the lead burden within the body becomes too high it will interfere with haemoglobin synthesis (Wittmers et al. 1981; Aufderheide and Rodriguez-Martin 1998, 318).

Lead absorption via the gastrointestinal tract is particularly efficient during childhood, and can be incorporated into the growing bone quickly, hence the greater the risk of lead poisoning in children (Kamenov and Gulson 2014). Lead replaces the calcium element in hydroxyapatite and may therefore be traced via chemical analysis in archaeological bone and teeth (Montgomery et al. 2010). Radiographically, lead poisoning is recognisable as ‘lead lines’, primarily at the metaphyses of long bones. These are areas of increased radiodensity as a result of incorporation of the metal into the bone matrix which in turn causes decreased osteoclastic function whilst osteoblasts continue to deposit new bone (Smith 1964; Leone 1968).

Lead content in bone, if differentiated from postmortem uptake is therefore indicative of anthropogenic manipulation of lead and allows inferences to be made on behaviour, including industrial and domestic activity (Budd et al. 2004). Lead does not occur in dangerously high concentrations naturally, however recurring and prolonged exposure to high lead concentrations, characteristic of an industrial and everyday use of the metal, will accumulate lead to toxic levels (Kwong et al. 2004). A chronic lead poisoning hypothesis during the Roman era is indeed feasible due to the extensive use of the metal (Wittmers et al. 2002; Montgomery et al. 2010). Lead was widely used in metallurgy and the pipework for water supply, whilst it was also popular as a medicinal aid and used as a sweetener and additive in Roman cuisine (Hart 2001). Montgomery et al. (2010) pointed out the factors that need to be accounted for when attempting to attest lead overexposure in archaeological bone. Depending on the burial environment and the length of interment, bone may take up lead postmortem. A range of ages-at-death can also skew the evidence for lead poisoning due to differences in exposure time. Lead uptake in living bone is subject to individual metabolism and health.

Lead has a long residence time within the skeleton of over 27 years, it accumulates with age and may be released back into the blood stream. Additionally, the representativeness of samples taken from different bones for trace element analysis varies. Bone is a living tissue, and the modelling and remodelling process of healthy bone turnover follows different velocities along varying time scales. Therefore, the lead signatures extracted from different elements of the skeleton may fluctuate and need to be accounted for (Montgomery et al. 2010).

2.2.6.3.5. Genetic anaemia

Genetic anaemias such as thalassaemia, sickle-cell anaemia, congenital haemolytic anaemia and erythroblastosis fetalis may be recognisable in the osteological record (Aufderheide and Rodriguez-Martin 1998, 347-348). Some genetic anaemias, such as thalassaemia, yield facial and postcranial changes that aid in their diagnosis (Hershkovitz et al. 1997; Keenleyside and Panayotova 2006). Since both thalassaemia and sickle-cell anaemia are endemic to the Mediterranean rather than Britain, it is important to view individuals with these diagnoses in their respective cultural and contemporary context. For example, diagnosing thalassaemia in children in Roman Britain has important implication, i.e. that they were born to immigrant parents and either migrated with their family or represent second-generation migrants (Lewis 2012).

The alterations of the haemoglobin molecules and red blood cells in thalassaemia and sickle-cell anaemia give the carrier an increased immunity to malaria (*Plasmodium vivax* and *Plasmodium falciparum*) (Hershkovitz et al. 1991; O'Donnell et al. 2009). These genetic anaemias are therefore a result of genetic polymorphisms perpetuated by a resistance to malaria. Heterozygous individuals display partial immunity, whereas homozygous carriers are fully immune but suffer from sickle-cell anaemia or thalassaemia which are the genetic anaemias recognisable in the palaeopathological record (Mitchell 2003; Ustundag 2011). However, recognising non-adult thalassaemia in the skeletal record has only recently come into focus (Lewis 2012).

Thalassaemia manifests in three clinically distinct forms. Thalassaemia minor which is mainly asymptomatic and yields a very limited or no skeletal response. Thalassaemia major is the most severe and extreme form, and present day sufferers rely on blood transfusions to survive. In the past, it is most likely that those affected will not have survived for longer than the first two years of life. Mild forms of thalassaemia major or thalassaemia intermedia are those discernible in the archaeological record. The affected individuals exhibit gross skeletal changes in response to the genetic anaemia but are able to live into later life (Lagia et al. 2007). Although both thalassaemia and sickle-cell anaemia trigger a hyperplastic marrow response and share the same bony changes, it is possible to differentiate between both conditions. Osteopenia and osteomyelitis can be observed in cases of both thalassaemia and sickle-cell anaemia (Almeida and Roberts 2005; Tyler et al. 2006). Facial involvement, described as the characteristic 'rodent face' is distinctive of thalassaemia. Porotic hyperostosis which occurs in thalassaemia and sickle-cell anaemia is more expressed in the former, 'hair-on-end' also tends not to be seen in cases of sickle-cell anaemia (Hershkovitz et al. 1997). The most common complication in sickle-cell disease is vaso-occlusive crisis, when blood vessels are congested by sickle-cell red blood cells and circulation is hindered. Vaso-occlusive crisis may lead to bone marrow infarction. If the infarction involves an epiphysis, it can lead to joint effusion, and the abnormal build-up of joint fluid may in turn trigger arthritic changes. In children up to seven years old, dactylitis may occur due to vaso-occlusive crisis and is most frequent in 1-2-year olds. Similarly, if the infarction affects the vertebral bodies, their collapse results in the characteristic 'fish mouth' appearance (Fig. 2.9) (Almeida and Roberts 2005).

Figure 2.9. MRI scans. Patient suffering from sickle-cell anaemia with 'fish mouth' appearance/concavity of vertebral bodies due to collapse on the left. Normal unaffected spine on the right for comparative purposes (from Ganguly et al. 2011)

2.2.6.4. Harris lines

Harris lines, or 'lines of arrested growth', are radio-opaque transverse lines at the metaphyseal ends of long bones (Mays 1985; 1995). Additional means of visualising these lines are electron microscopy, magnetic resonance or histological cuts of the affected bone (Alfonso-Durruty 2011). The formation of Harris lines has been traditionally interpreted as a stress response. After a period of non-specific physiological stress has terminated, whereby the stressor was severe enough to cause growth to tail off or cease, a transverse layer of highly mineralised trabeculae will be evident (Aufderheide and Rodriguez-Martin 1998, 422; Papageorgopoulou et al. 2011). However, Lampl et al. (1992) observed that growth in children is a saltatory process, where longitudinal growth is characterised by short bursts of increased growth velocity, rather than a gradual attainment of height. Stasis as the growth-free state may account for over 90% of the growth period. Arrested growth is therefore not a pathological process but in keeping with individual spurts. Recent research on growth in rabbits has put the stress-indicator hypothesis further into question by demonstrating the formation of Harris lines during periods of rapid growth in the absence of nutritional stress (Alfonso-Durruty 2011). Yet, the applicability of these results has not been established for human populations. Careful observation and interpretation of Harris lines is still a useful tool in the analysis of health profiles, although we are limited by their non-specific nature (Nowak and Piontek 2002). If their presence and severity is cautiously judged in terms of the presence of general stress, Harris lines can still be included in the palaeopathological repertoire.

2.2.6.5. Trauma

Trauma to bone results in skeletal injury, which include displacement or dislocation, interrupted blood or nerve supply, artificial alterations to the shape of bone, and complete or partial breaks (Ortner 2003, 119). Bone will break under the strain of both direct, or indirect external forces that exceed its elasticity and tension (Aufderheide and Rodriguez-Martin 1998, 20). It is vital to bear in mind that immature bone exhibits different mechanical properties than mature adult bone. Subsequently different distributions of fracture patterns may result, characteristic to the porous, weak and highly cartilaginous qualities of paediatric bone. Greenstick fractures, torus or buckle fractures and plastic deformations are most commonly encountered in immature bone. The unfused elements in non-adult bone also initiate different fracture types and corresponding healing patterns, such as fractures at the growth plate. Healed fractures may also lose visibility in the palaeopathological record due to the fast response in remodelling of growing non-adult bone (Lewis 2007, 163-165; 2014; Verlinden and Lewis 2015).

2.2.6.6. Dental disease

By investigating dental disease in non-adults, information on the childhood diet can be obtained. This in turn informs on not only the type of foods consumed, but also their preparation and accessibility which is mediated by status. Periapical lesions or abscesses, calculus, periodontal disease and antemortem tooth loss are rare in children. Hence rates of carious lesions in the deciduous and permanent teeth provide the most effective measure of child dental health in the past (Halcrow et al. 2013). According to Bradley (1998), Roman children were supposed to eat a simpler diet than adults, although we do not know which foods exactly. At Isola Sacra, dental pathology and isotopic studies have revealed a reliance on soft carbohydrates past the age of 2.5 years as well as a predominantly terrestrial diet (Prowse 2011; Prowse et al. 2008). Isotopic work on non-adults and adults from Roman London has shown that it is unlikely children consumed an adult diet (Powell et al. 2014). Yet, the Romano-British childhood diet past the weaning age remains largely unknown. In children, caries will spread from mother to child via kissing or sharing utensils, and can inform on the types of foods consumed, such as carbohydrates or refined sugars (Nield et al. 2008). Caries can cause considerable discomfort for the individual, causing pain, difficulty in eating, even suppressing efficiency of the immune system (Bagain et al. 2004). In children, caries infections can also affect speech development (Aligne et al. 2003). Period-based dental health studies are rare in the palaeopathological literature for Roman Britain and tend to focus on individual site analyses or small non-adult sample sizes (see section 3.3). Comparisons between published data may also be hindered by the way in which carious lesions, antemortem tooth loss or abscesses are recorded or the data presented. For example, some authors do not divide teeth into deciduous or permanent, while others divide the teeth into posterior and anterior, or make no such distinction. Percentage rates may be presented as crude prevalence rates (CPR) based on the number of individuals affected, or true prevalence rates (TPR) based on the number of teeth affected, while some researchers follow Lukacs (1995) and include teeth lost antemortem into their caries scores.

In the current study, the discussion of dental disease comprises of caries, antemortem tooth loss, and inflammation and infection of the alveolar bone (Hillson 1996, 254-287). Caries is a progressive infectious disease of both the deciduous and permanent dentition, with localised demineralisation of the dental tissues due to organic acids (Larsen 1997, 65). *Streptococcus* *mutans* and *streptococcus sobrinus* in the oral cavity metabolise sugars and starches which create an acidic environment. Teeth are remineralised as soon as pH levels are restored to neutral. If however, the pH is low for a prolonged period, the dynamic between demineralisation and remineralisation is upset, and a cavity in the tooth enamel results (Gussy et al. 2006). *S. mutans* is normally transmitted from the mother or other main care giver through kissing or sharing implements (Gussy et al. 2006; Kawashita et al. 2011). Colonisation with *S. mutans* and *S. sobrinus* can commence as early as six months old, although the highest risk for infection is at two years old. It takes around 13-16 months from colonisation until carious lesion development (Kawashita et al. 2011). Early childhood caries, defined as more than one tooth affected by caries in children under six years old, may take on a rampant virulent form. Known as severe early childhood caries (also nursing caries or milk bottle syndrome), this is characterised by rapid lesion development and dental decay primarily in the maxillary anterior dentition (Azevedo et al. 2005; Berkowitz 2003).

Diet is a crucial factor in influencing the incidence of caries. Sweet and sugary, and carbohydrate-rich foods encourage the metabolic activity of oral bacteria and acid production, therefore increasing the risk of lesion development (Powell 1985; Prowse et al. 2008). Other factors include the means of food preparation (Bonfiglioli et al. 2003), and the amount and periodicity of foods consumed (Halcrow et al. 2013). A tough and fibrous diet has a cleaning effect on teeth, and vigorous mastication stimulates salivary flow. This acts as a buffer against plaque acids surrounding the teeth due to its alkaline nature (Duray 1992, 308; Moynihan 2000). Whereas soft and sticky foods, and prolonged snacking or sipping of sweetened fluids pose a greater risk for acid development (Hallett and O’Rourke 2003). The location of the carious lesion on the affected tooth will also vary according to dietary regimes. Caries rates are generally low when starch-rich plant foods form a major part of the diet. Caries rates at the root and cemento-enamel junction rise with the intensification of cereal agriculture. As more and more sugar gets introduced, the incidence of interproximal and fissure caries increases, especially in children (Moore and Corbett 1973; Hillson 1993, 283).

A dental abscess may form by bacterial infection of the pulp cavity secondary to caries. The inflammation will produce pus, which will have to drain and form a cavity in the alveolar bone (periapical lesion) (Hillson 1993, 285-286). In archaeological bone, an abscess can only be identified via radiographs or once it has perforated the alveolar bone (Roberts and Manchester 2010, 70). Teeth may be lost during life owing to inflammation secondary to caries, periodontal disease, periapical lesions or poor oral hygiene. In archaeological populations, antemortem tooth loss can be distinguished from postmortem loss by observing any remodelling of the alveolar bone (Larsen 1997, 77-78; Roberts and Manchester 2010, 74).

The investigation of dental disease, particularly caries, is therefore a valuable means to approaching childhood diet in Roman Britain.

2.2.7. Weaning stress

The weaning period may expose infants to a particularly high risk of dietary and environmental stress due to compromised nutritional and immunological status. This period therefore deserves to be discussed in its own right. The introduction of supplementary solid foods during transitional feeding is necessary from around six months old, as breastmilk alone cannot meet the nutritional demands of the growing child anymore (Whitehead and Paul 1984; Katzenberg et al. 1996; McDade and Worthman 1998; Fewtrell et al. 2007; Sellen 2007; Katzenberg 2012, 105). However, the infant also has to achieve certain developmental and physiological milestones to be fed increasingly solid foods, such as sitting up and the attainment of oral skills (Rogers and Arvedson 2005; Delaney and Arvedson 2008; Humphrey 2010). The child is then fed a diet of supplementary foods together with breastmilk, until the amount of breastmilk given will be gradually reduced and weaning is complete.

The introduction of supplementary foods carries risks, increasing morbidity and mortality via new pathogens and ingestion of unfamiliar foodstuffs. This creates a dilemma for the infant between increased nutritional demand to support larger body and brain size versus amplified pathogen exposure and strain on the digestive system (Humphrey 2010). Especially during the second half of the first year, the nutritional requirements of the infant outweigh the risks associated with transitional feeding, and supplementation is paramount (Pearson et al. 2010). Even though weaning introduces health hazards, the fitness trade-offs of nutritional adequacy to ensure a basis for healthy development and growth, especially of the brain, are favoured (Kennedy 2005; Humphrey 2010).

Infant feeding will influence the physiological, metabolic and possibly even psychological constitution of both mother and child (Stuart-Macadam 1995, 25; Sellen 2007). Breastfeeding is beneficial to infant health as associations between higher risk for gastrointestinal and respiratory illness as well as infectious disease have been found in bottle-fed/formula-fed infants (Cunningham 1995, 244-245; Wold and Adlerberth 2002). In a society where no baby formula is available, these risks would be greatly increased. Similarly, nutritional deficiencies in the breastfeeding mother can impact on the weanling's health, as can prolonged breastfeeding without supplementation (Clark et al. 1992; Buckley 2000; Brickley and Ives 2008, 45, 86; Popovich et al. 2009; Holley et al. 2011; Lahner et al. 2012; Halcrow et al. 2014; Pettifor 2014).

Breastfeeding and weaning are adaptive processes that are influenced by biocultural, crosscultural and evolutionary pressures (Hammer et al. 1999; Sellen 2007). Apart from the socioculturally mediated duration of breastfeeding and weaning, some cultural spheres both past and present deem early breastmilk (colostrum) a taboo although it is highly concentrated in substances beneficial to the child (Salariyah and Robertson 1993; Nyinah 1997; Oddy 2001). Substitutes for breastmilk may have included goat's and cow's milk in the past, however the proteins within cow's and goat's milk cannot be tolerated by the infant's developing gut flora (Tomas 2009). Cow's milk especially is rather harmful, causing diarrhoea through protein intolerance, and not meeting nutritional requirements (Schrander et al. 1993; Stuart-Macadam 1995, 18-19). Infant mortality is raised during the initial period of introducing supplementary foods (Herring et al. 1998), and if the high nutritional requirements of the infant are not met, mal- or undernutrition will result. This in turn may be detected in the skeletal record. Lesions such as porotic hyperostosis and cribra orbitalia may arise, alongside disruptions in the formation of tooth enamel (Lewis 2007, 97). Scurvy and rickets as a result of vitamin C and D deficiencies, or depleted calcium stores may also occur. Detecting evidence for breastfeeding and weaning patterns skeletally can therefore yield information on infant rearing practices, maternal and child health, cultural influences and identities, and the mother-child relationship.

Methods of chemical analysis such as stable isotopes are another means to exploring infant feeding and the cessation of breastfeeding. Stable isotope ratios of nitrogen, oxygen, strontium and calcium vary within bone, depending on the trophic level of the individual. The breastfed infant will have similar isotope ratios to its mother, but by occupying a higher level in the food chain however, the assumption is that the infant's nitrogen levels will be enriched until weaned (Tsutaya and Yoneda 2015). Carbon and oxygen isotope analysis can point out water sources and a cereal based weaning diet. C13 levels in bone increase as C4-plants are ingested and O18 levels decrease as the infant receives less breastmilk (Wright and Schwartz 1999). Fuller et al. (2006b) observed a faster decline in C13 than N15 levels in infants when weaned, using a modern study population of infants and their mothers. Their observations suggest that the decline of C13 in breastfed infants once weaned is not solely due to the introduction of C4-foods but may be used as a general marker for solid foods in the diet. The decline in N15 levels with the onset of weaning is more gradual and dependent on the length of time breastmilk had been consumed. N15 levels may therefore be used to indicate the length of time an infant has been breastfed. A limitation of the applicability of these findings may be encountered in archaeological contexts. Fuller et al. (2006b) collected their samples from fingernails and hair, whereas samples from archaeological skeletons may show different time spans for isotopic signatures. The turnover of bone collagen is slower, hence there is a time lag in the manifestation of isotope levels, compared to hair and nails. General concerns in the current interpretation of isotopic signatures for the identification of breastfeeding and weaning patterns have also been pointed out. Beaumont et al. (2015) emphasised that our findings are based on adults, infants and young children who did not survive, which is a general limitation of any observations made in the study of non-adults. Breastfeeding habits and weaning behaviours determine the health and survival of children, and the samples we can observe in the archaeological record may therefore be biased towards those who were subjected to a regime that was detrimental to their health. The N15 profiles obtained from teeth of Irish and British 19th century children showed marked disparity between those who survived early childhood and those who did not, where the former group did not show a peak in N15 indicative of breastfeeding. Therefore the relationship between N15 isotopes and weaning in archaeological populations is not as straightforward as previously believed (Beaumont et al. 2015). The use of nitrogen as a marker for weaning in past populations has received more criticism by Reynard and Tuross (2015). The authors pointed out how isotopic case studies using small sample sizes should not be taken as entirely representative of weaning behaviours for a population or time period. Some of the basic assumptions made with the isotopic study using nitrogen to establish weaning should also be challenged. The female or adult mean of N15 at any given site may not necessarily reflect the mean of the mothers who were breastfeeding. Mother and infant may also not have the same isotopic ratios at birth. Additionally, the N15 offset of the mother's bone collagen to her breastmilk is presumed to be nil, when breastmilk in fact has a lower N15 signature than maternal collagen (de Luca et al. 2012; Romek et al. 2013; Reynard and Tuross 2015). The N15 isotopic signature for infants is also influenced by individual isotopic offsets, tissue-specific uptake, differences in the gut microbiome of every infant and faster protein turnover generally observed in this age group. The N15 levels obtained may also differ depending on the type of tissue, i.e. bones or teeth, and bone element used for analysis (Hedges and Reynard 2007; Jørkov et al. 2009; Reynard and Tuross 2015). The isotopes of oxygen, sulphur, and calcium-standardised strontium or barium may be overall more suitable for identifying dietary changes in proteins and plant foods, and distinguishing the transition from breastmilk to only solid foods (Tsutaya and Yoneda 2015).

2.3. ROMAN BRITONS OR BRITISH ROMANS?

How Roman was Roman Britain? This is a question that as of yet remains unanswered and continuously challenged. Whereas acculturation of the local Iron Age population did indeed take place, Roman influence may not have been as overpowering as previously thought (Grubbs 2005, 95; Pitts 2008). Contact with Roman customs and 'Romanised' societies had taken place before the invasion in AD 43 (Shotter 1998, 67; Haselgrove 2004, 25; Pryor 2004, 2-3; Millett 1990, 8; Williams 2007; Pitts 2010). Yet, as Williams (2007) has elaborated via an analysis of Iron Age coin inscriptions, there is regional diversity in the extent of absorption of Roman culture. Until the early 5th century AD, Roman Britain reflected a cosmopolitan and diverse society, with migration within the Empire impacting on religious beliefs, customs and social organisation (Eckardt 2010a,b). Immigrants to Roman Britain may not have been Roman in the strict sense but rather 'Romanised' locals from other provinces of the Empire (Allason-Jones 2004, 273; Grubbs 2005, 95).

The army probably was one of the driving forces behind Romano-British multiculturalism, as soldiers were recruited from Rome and the provinces. Although not strictly legal, these men would often marry during service, their wives and children living nearby, and ultimately settling in close vicinity to their former fort on honourable discharge and citizenship (Burn 1970, 82, 100; Shotter 1998, 72, 75; Korporowicz 2012). Prominently within the provinces, military settlements strictly adhered to Roman ideology, every fort reflecting a diminutive Rome (Henig 2004, 225). A quote by Dio Cassius (*56.18, 2-3* as cited in Shotter (1998, 66) about 'Romanisation' on the Continent reflects the general sentiments behind this concept of colonialism and the propaganda associated with Roman Imperialism.

"The barbarians were adapting themselves to Roman ways, were becoming accustomed to hold markets, and were meeting in peaceful assemblages. They had not, however, forgotten their ancestral habits, their native manners, their old life of independence, or the power derived from arms. Hence, so long as they were unlearning these customs gradually and by the way, as one may say, under careful watching, they were not disturbed by the change in their manner of life, and were becoming different without knowing it."

The gradual acclimatisation of the conquered population was encouraged (Burn 1970). Shotter (1998, 67-68) also put forward that Iron Age societies were built around wealth generation, hence the presence of the army might have been welcomed by some Britons, especially the elite seeking new economic opportunities. Latin rights and citizenship however had to be earned and granted to the native population, and may have become a status symbol (Korporowicz 2012).

The concept of 'Romanisation' has been on the academic agenda for over a century. How we study the uptake of Roman culture across Britain, and the empire in fact, is dependent on the national and imperial contexts in which the subject itself is debated. Models on the spread and uptake of *Romanitas* have therefore changed considerably since Antiquarians first pondered the question (Hingley 2008). The 'Romanisation' of Britain was initially interpreted as colonialism. Gradually, the colonial framework weakened however, and it was accepted that Roman culture may not have been an overriding power that eliminated native culture (Woolf 1997). The current state of knowledge suggests a blending of cultural values rather than replacement (Millett 1990, 2005; Rawson 2003b; Mattingly 2006; Pitts 2008). A creolisation model has recently been suggested as a better suited means to describe the process of 'Romanisation' in Britain (Carr 2003). The term thereby suggests the creation of a distinct culture by assimilating different features and aspects from both local and other incoming cultures (Webster 2001; Mattingly 2004; 2006, 14-17). The process of creolisation within the Roman provinces was not uniform across the geographic and demographic layers of the respective area (Webster 2001; Redfern and Gowland 2012). The arrival of 'Roman-ness' would have therefore promoted social complexity across Roman Britain rather than diminishing it (Woolf 1997). It remains to be investigated how this impacted on the lifeways of the people across Roman Britain and its social strata.

The current research has got the potential to add to this debate, as non-adult osteology is able to give an indication of some aspects of social change in late Roman Britain. Palaeopathology is a gateway to exploring a wealth of information on non-adult skeletons, including lifestyle, diet, mobility, living conditions and status. These insights are particularly helpful in trying to understand everyday realities of the common Romano-British population. Palaeopathological data provides a primary form of evidence for the life course of Romano-British children which goes beyond any references in the Classical literature. The archaeology of Roman Britain has been dominated by the structures of the elite and how concepts of power and wealth are displayed in settlements, thereby neglecting the lives and narratives of the majority of the population. The health and stress observed in non-adult skeletons reflects the social, cultural and biological wellbeing of the population as a whole. Investigating skeletal health will also allow us to monitor how well the stereotypical Roman lifestyle and recommendations for child rearing and the life course took hold in the province.

CHAPTER 3. CHILDHOOD HEALTH IN ROMAN BRITAIN

Previous regional and site-specific studies on the palaeopathology of Romano-British children provide important insights into growing up in *Britannia*. Some of the social and cultural processes that have shaped the life course of children, and the population as a whole, are presented in these studies based on the treatment children received and the ailments they suffered from. Previous findings also serve as an important basis for the current study, providing reference points for certain patterns of ill-health and disease which we might expect to find in specific settlements. These studies have also established a link between ill-health and stress in Romano-British children that would have arisen due to 'very Roman' practices from the centre of the Empire itself. Therefore, aspects of the childhood experience in Rome, obtainable via the Classical written, iconographic and epigraphic sources, also have to be considered, as the provinces were clearly influenced by Roman culture.

Using Classical sources in isolation creates immediate bias for the study of Romano-British childhood, but we may be able to tease out information that is relevant to child health and the findings of previous studies, as well as those forthcoming in the current study. This chapter will first review previous work on the palaeopathology of Romano-British children, and then consider the evidence for Roman childhood in the centre of the Empire from written (literary and epigraphic evidence) and iconographic sources. This includes aspects relevant to the life course of Roman children, as well as current debates such as the one surrounding the evidence for infanticide and differential burial practices for those dying in infancy.

3.1. THE PALAEOPATHOLOGY OF ROMANO-BRITISH CHILDREN

In 2003, Roberts and Cox discussed health and disease in Roman Britain, providing a broad overview of patterns of ill-health in adults primarily. The chapter illustrated a high prevalence of ill-health among Romano-British populations, especially those of urban contexts (Roberts and Cox 2003, 107). Overall, evidence for an increase of congenital diseases, specific and non-specific infections, tuberculosis, anaemia and metabolic disease from previous time periods was found (Roberts and Cox 2003, 163). Roman administration is often associated with the benefits of improved water supply, sanitation and administration (Millett 1990, Mattingly 2006). However, the observations by Roberts and Cox (2003) provided a conflicting new outlook, suggesting an environment that was harmful to the local population, especially those in urban environment and of lower social status. These findings have recently been validated by Pitts and Griffin (2012) and Redfern et al. (2015) who demonstrated that it was not only those living in the towns, but the rural populations especially who suffered from compromised health indicative of poor diet and strenuous lifestyles. Regarding childhood health specifically, there are a number of recent osteological studies of Romano-British non-adult populations, albeit regional or site-specific.

Redfern and Roberts (2005), for example, discussed health in Romano-British urban populations from London, Dorchester, York, Colchester, Chichester, Ilchester and Cirencester by studying the skeletal data available from osteological reports. Four age groups were used for the non-adult sample, infant (0-3 years), child (3-6 years), juvenile (7-11 years) and adolescent (12-18 years). Overall, adolescents exhibited the lowest rate of stress indicators (cribra orbitalia, dental enamel hypoplasia and periostitis), and more evidence for metabolic than infectious disease was found in juveniles. In children, the prevalence and severity of stress indicators varied between sites and was concentrated in London and Colchester (Redfern and Roberts 2005, 117). As a general trend, evidence for stress and mortality declined with increasing age and was generally higher in urban than in rural environments (Redfern and Roberts 2005, 122).

Nitrogen, carbon and sulphur isotope analysis of non-adult individuals from Queenford Farm in Oxfordshire has yielded valuable insight into the timing of weaning and the nature of the weaning foods consumed. The managed Roman cemetery at Queenford Farm relates to a small unnamed Roman town in the close vicinity, near the present-day village of Dorchester-on-Thames (Chambers 1987). The age group from birth to about 18 months old was underrepresented and it was not possible to discern the onset of weaning. The isotopic signatures of young children indicated cessation of breastfeeding between the ages of 2-4 years with a large component of cereals in the weaning diet, and terrestrial and freshwater protein administered via breastmilk (Fuller et al. 2006a; Nehlich et al. 2011). The completion of weaning at around 3-years old has also been validated elsewhere in Roman Britain, i.e. Dorset (Redfern et al. 2012) and London (Powell et al. 2014), as well as in other areas of the Roman Empire, for example in Egypt (Dupras et al. 2001). Compared to what we can discern from the Roman literature, this is a long period of breastfeeding. Soranus (II 46[115]) recommended the introduction of weaning foods at six months old (Temkin 191, 117). The infant was then to be taken swiftly off the breast following dental eruption at around 18 months old (Rawson 2003a, 126). A slightly younger weaning age at Portus near Rome has also been validated isotopically by Prowse et al. (2008) at around 2.5 years old. Perhaps, weaning practices varied slightly across the centre and margins of the Empire.

At Wetwang Slack, a pre-Roman Iron Age site in Yorkshire, isotope analysis of children recovered from the 4th-2nd century BC burial ground showed a cessation of weaning at around 2-3 years old. This is similar to the Romano-British weaning pattern discussed in Fuller et al. (2006a), Nehlich et al. (2011) and Redfern et al (2012). It has however been noted that the onset of weaning was consistently at a later point in Iron Age populations, roughly around the end of the first year of life (Jay et al. 2008). Unfortunately, no data on the onset of weaning is available from Queenford Farm to compare with the practices followed at Wetwang Slack. However, Powell et al. (2014) attested that supplementary foods would have been given by six months in children from Roman London, which is distinctly earlier than the timeframe suggested at Wetwang Slack.

An additional isotopic study was undertaken by Redfern et al. (2012), comparing nitrogen and carbon isotope ratios in non-adults from Roman and Iron Age Dorset, also taking dental health and metabolic disease into account. The findings show continuity in infant feeding practices between both time periods, and indicate a weaning diet that was low in marine foods, or alternatively a restricted diet for lactating mothers. The latter has also been suggested for the isotopic signatures of females and children in Roman London (Powell et al. 2014). Simultaneously, an increase in metabolic disease was observed in the Romano-British, compared to the Iron Age non-adults from Dorset. The decline in health in Romano-British infants and young children may be linked to earlier weaning and changes in introductory foods, which Redfern et al. (2012) argue may reflect an amalgamation of traditional Roman and local Iron Age infant feeding practices.

The children from the cemetery at Poundbury Camp in Roman Dorchester, Dorset, mark one of the most extensively studied Romano-British non-adult cohorts. Molleson (1989) first interpreted the mortality patterns of the non-adults, and described age-dependent differences in burial treatment and representation within the cemetery. Baptism as a rite of passage was suggested as the reason for the low numbers of full-term perinates and premature babies within the excavated cemetery area. In adolescents, burials of females outweighed those of males, and it was argued that this was an effect of girls within agrarian societies experiencing a higher mortality risk due to lower status. These gender-related socioeconomic differences would be reflected in neglect, differential care and restricted access to resources for females (Molleson 1989). However, this hypothesis poses two distinct problems. The higher female to male ratio in the adolescent age category may be skewed. The adolescents were sexed using tooth crown morphology, based on a discriminant function analysis which was derived from adult tooth dimensions of the same population. Although it is recommended to establish a baseline group with known sex to infer sexual dimorphism in crown dimensions (Hillson

1996, 81-82), Molleson's (1989) approach is not repeatable. Sex estimations based on tooth crown dimensions may be faulted due to environmental and genetic influences, and small size differences between the sexes may lead to higher observer error (Garn et al. 1979; Hillson 1996, 82; Harila-Kaera et al. 2001; Harila et al. 2003). Most importantly Roman society may not have awarded lesser status to females. Women and children were formally educated alongside their male peers and held jobs, family responsibilities and managed estates (Harlow and Laurence 2002, 58). Equally, there is evidence for some pre-Roman Iron Age tribes with social equality between the sexes, and tribal leadership by women was not out of the ordinary, as demonstrated famously by Boudicca (Allason-Jones 2004, 273-277).

In a later study of metric data, trace element analysis, morbidity and mortality, Molleson (1992) proposed that 'Romanisation' brought about a general deterioration in child health throughout the 500 years of use of the Poundbury Camp burial ground. Observations on differential treatment of perinates, and the presence of skeletal and dental indicators of dietary and environmental stress, mainly stunted growth and enamel hypoplasia, gave first insights into non-adult health in a Romano-British town. Just one year earlier, Stuart-Madam (1991) published her study on porotic hyperostosis and cribra orbitalia in the Poundbury Camp assemblage, including the children. The results were interpreted as high levels of acquired iron-deficiency anaemia, primarily in young children, attributed to infectious disease, parasitic infections and lead poisoning. An earlier isotopic study regarding the possibility of lead poisoning at Roman Dorchester was undertaken by Molleson et al. (1986), who found high, potentially toxic concentrations of lead in skeletal remains. Lead poisoning is notoriously difficult to identify in buried bone using trace elements (Montgomery et al. 2010). Waldron et al.'s (1976) paper on the lead content of bone dating to the Romano-British period served as a basis for Molleson et al.'s (1986) work, but the study was later discredited by Waldron himself (Waldron 1983). Nevertheless, lead was extensively mined and widely used in Romano-British society. Exposure to lead in a domestic and work environment as well as its presence as a dietary contaminant will have forced high uptake of the metal (Hernberg 2000).

The full extent of skeletal evidence for ill-health in the Poundbury Camp children was re-evaluated in palaeopathological studies by Lewis (2010; 2011; 2012). The total sample of 364 late Roman non-adults aged 0-17 years showed high levels of cribra orbitalia, metabolic disease and trauma. Cribra orbitalia was observed in 38.5% of non-adults with orbits, and rickets or scurvy were present in 11.2% of individuals. The burial patterns within the cemetery are not uniform and two distinct styles can be differentiated. One is interpreted as the managed Roman 'Christian'-style layout with graves aligned east-west, and the other a more pagan set of graves with north-south alignment. Evidence for rickets and anaemia was found in both groups, but children from the 'Roman' graves included more scorbutic individuals and rib fractures (Lewis 2010). Lewis (2010) interpreted these findings as indications for differences in child rearing and infant feeding practices among two social groups, one maintaining native practices and the other more inclined to following Roman paradigms, favouring changes in dietary habits and possibly tight swaddling. In Rome itself, the diet of the poor was based on cereals which would have caused a range of dietary deficiencies, and a similar shift may have occurred at Poundbury Camp (Prowse et al. 2005; Britton and Huntley 2011). Swaddling is mainly seen as a beneficial childcare practice, promoting mother-infant bonding and lowering the risk for Sudden Infant Death Syndrome (Yurdakok et al. 1990; Kutluk et al. 2002; van Sleuwen et al. 2007). However, it has been suggested that swaddling in the children at Poundbury Camp may have had adverse health outcomes (Lewis 2010). The practice may potentially lead to rib fractures in bone weakened by rickets if the child is wrapped up too tightly or held carelessly. Swaddling clothes also have the potential to minimise the skin's exposure to sunlight, especially if children are kept indoors for prolonged periods.

The Poundbury non-adults also exhibited lesions indicative of childhood tuberculosis (Lewis 2011). A high level of infection may indicate a crowded living environment, close contact with animals, in addition to high smoke or dust exposure which compromise healthy lung function and increase the risk for respiratory infections. These observations suggest an urbanised environment, overcrowding, inadequate sanitation and pollution of the air (Roberts and Buikstra 2003; Lewis 2011).

Certain diseases which are recognisable in the osteological record may serve as markers for migration. It is important to bear in mind that migration was not only dependent on commerce and the army, but that people in the Roman Empire would have also travelled for family or private business, as well as seasonal availability of work (Leach et al. 2009; 2010; Eckardt 2010a,b; Eckardt et al. 2014). Eckardt et al. (2014) reiterated that recent isotopic and osteological studies have shown that it was not just young adult males who travelled but also whole family units, women and children. The presence of probable cases of thalassaemia in the children from Poundbury Camp further adds to our knowledge on mobility in the Roman Empire (Lewis 2012). Within the Poundbury Camp assemblage, three children were found with lesions indicative of this type of genetic anaemia. Since thalassaemia is not endemic to Britain, individuals displaying this condition must have migrated to Roman Britain from warmer climes where the condition is more common, such as the Mediterranean, suggesting that these children were born to immigrant parents (Lewis 2012). Previously, the diagnosis of thalassaemia has been hindered by a lack of pathognomonic features and the non-specific nature of cribra orbitalia and porotic hyperostosis (Ortner 2003, 364-365). Lewis (2012) however demonstrated that changes in the thorax alongside lesions attributed to anaemia can be interpreted as skeletal manifestations of thalassaemia in non-adult skeletons. Ribs appear thickened on the visceral aspect of the shaft whilst also showing pitting on the intercostal margin. Costal osteomas and the radio-opaque appearance of a 'rib-within-a-rib' have also been noted as suggestive of this type of genetic anaemia (Lawson et al. 1981; Tunaci et al. 1999). Nevertheless, finding this disease in archaeological child skeletons is rare, and children suffering from the more severe β-thalassaemia major would not have survived in the past. Romano-British Dorchester may have been unusual in terms of its population composition compared to other Romano-British towns, and accommodated more migrants from the Mediterranean. Alternatively, other sites may have had an immigrant population too, but with fewer carriers for β-thalassaemia, or the children suffering from it have simply not survived in the burial environment or been excavated to be reported, studied and discussed today.

Additional studies have allowed insight into childcare and parental investment in Roman Britain, as the choices made by the caregiver will directly affect child health and are indicative of different stages in the life course of children (Redfern and Gowland 2012). Shifts in cultural practices, foodways and environment will therefore impact on non-adult palaeopathology, and can be used as a tool to describing the effects of 'Romanisation' (Redfern 2007). In a regional study, Redfern (2007) assessed skeletal markers of stress and disease in those aged under 20 years old, including 80 Iron Age and 110 Romano-British individuals from Dorset. Rickets was particularly prevalent among 0-3 year olds from the Roman period, pinpointing changes to young child care and the weaning diet which negatively impacted on health. The mortality rate within 3-7 year olds was elevated in the Romano-British compared to the Iron Age sample, interpreted as a result of infectious disease on the rise. Lastly, more cultural and environmental stressors may have acted on the Romano-British children as their femoral growth patterns lag behind those of Iron Age children from around three years old. Overall, Redfern (2007) discerned a pattern of declining health between both time periods, especially in the youngest age groups. Some of these would have been due to environmental and cultural changes which can be related back to concepts of 'Romanisation', and new behaviours adopted by the native population, such as weaning habits or increasingly urbanised dwelling.

Gowland and Redfern (2010) have pointed out the need for a contextual discussion of ill-health and stress in Roman Britain with reference to patterns seen elsewhere in the Empire. Skeletal remains from Roman London and the city of Rome were selected to illustrate disease and wellbeing in the centre and at the fringes of the Empire. Levels of ill-health were generally elevated in urban environments, as validated in previous studies across the cemeteries of Imperial Rome (Cucina et al. 2006). The data of the city of Rome from the cemeteries at Via Collatina, Via Basiliano and Casal Bertone of the eastern suburb, and Osteria del Curato I and II of the southeast suburb with contemporary Italian sites of different settlement types indicated a shared poor standard of living and diet. *Londinium*, including inhumations and cremations recovered from the northern, eastern, southern and western cemeteries, as well as one intramural burial at Baltic Exchange, was characterised by a higher rate of adult skeletal pathologies than elsewhere in *Britannia* indicating poorer health and a more restricted diet. A comparison of adult and non-adult skeletal data from the city showed a higher rate of cribra orbitalia and enamel hypoplasia in the adults. These conditions are however influenced by stress during childhood, which the non-adults from *Londinium* did not express and therefore experience to the same extent. The authors concluded that the observations might be indirect evidence for an influx of migrants arriving in London during later life, probably originating from the Mediterranean (Gowland and Redfern 2010).

Gowland and Garnsey (2010) provided a study that addressed health, nutritional status and the prevalence of malaria by assessing cribra orbitalia and enamel hypoplasia as childhood conditions in skeletal populations from Rome and across the Empire. Cribra orbitalia and porotic hyperostosis, frequently observed in Italian Roman populations, may suggest anaemic conditions, although the aetiology of these marrow hyperplasias is still debated (Walker et al. 2009; Oxenham and Cavill 2010). These children may have acquired anaemia due to chronic illness or infection, early cessation or avoidance of breastfeeding, a weaning diet of phytate-rich cereals, or depleted iron stores of the mother/wet nurse. Alternatively cribra orbitalia and porotic hyperostosis may have arisen due to genetic anaemias (Harinarayan et al. 2007; Gowland and Garnsey 2010, 147), as seen in individuals carrying the β-thalassaemia gene mutation (Hershkovitz et al. 1997; Ortner 2003, 367). Malaria is well accounted for as an endemic disease in Classical Italy (Soren 2003). A high prevalence of the disease favours individuals with genetic mutations resulting in a form of resistance, which can manifest as β-thalassaemia amongst others (Ayi et al. 2004). Gowland and Garnsey's (2010) results suggest that there is a correlation between high rates of marrow hypoplasia and malarious areas as cribrotic lesions were particularly prevalent in Italian areas that presented favourable conditions for malaria infection. The Romano-British cohort used in the study was expected to have suffered from a similar poor weaning diet and inadequate sanitation as the Roman children, in theory resulting in similar rates of cribra orbitalia and enamel hypoplasia. Yet, the prevalence of either lesion was considerably lower. Roman Britain was comparatively under-urbanised (minor urban sites such as Queensford Farm/Mill, Baldock and Kempston were included in the sample) and malaria may have been virtually absent. These factors may have resulted in a lesser incidence of early childhood stress as enamel hypoplasia, and fewer individuals were affected by acquired anaemia and particularly genetic anaemia in response to a much more contained malarial threat (Gowland and Garnsey 2010).

3.2. THE CLASSICAL PERSPECTIVE: EVIDENCE FOR CHILDHOOD HEALTH FROM ROME

In order to provide a cultural framework for some of the morbidity and mortality patterns observed and expected in Romano-British non-adults, it is beneficial to be aware of relevant aspects of childhood described in the Classical literature. The following section will review the Roman life course of children and information on child-rearing practices; in each case an attempt is made to consider the health implications and whether or not these might be reflected in the osteological record. Additionally, both written and (osteo)archaeological sources will be considered to establish whether slavery had a major impact on the children of Roman Britain, or indeed means of limiting family size were practised. Of course, over-reliance on the written, iconographic and epigraphic evidence from Rome itself must be avoided to fully grasp how children in *Britannia* experienced growing up. We cannot be certain how much of the Roman childhood experience was relevant to those growing up in the most northwestern province, however we are able to glean certain aspects of childcare and –rearing that will be visible in the osteological record. Similarities and differences between practices described in the Classical sources and those detected in Romano-British child skeletons can therefore also help us characterise the cultural affiliation of Roman Britons.

3.2.1. The family: a child's environment

The different social environments (such as the family) that children were exposed to during the Roman period would have also shaped their physical environment and exposure to health hazards. The Roman *familia* comprised of two conceptual entities (Rawson 1986; 1991, 17). It may include the nuclear family only, or be used as a term to describe the entire household under the reign of the *paterfamilias* as head of the family. This clan is inclusive of the extended family, slaves, and men and women working for the *paterfamilias* (Dixon 1991; Saller 1994, 72-75; Thompson 2006; Dasen and Spath 2010). Divorce and high mortality characteristic to pre-industrial societies led to remarriages and a continuous shift in the family structure (Rawson 1991, 8-17; Harlow and Laurence 2002, 95; Kuefler 2007). These factors may have resulted in several generations of natural, step- or adopted children, as well as foster and illegitimate children, foundlings and orphans living within the same household. It was not only the parents who were in charge of caring for their children. Childcare in Rome would have been a joint effort, mainly between the mother, *nutrix* (wet nurse) or *paedagogus* (teacher) among richer families (McWilliam 2013, 277; Sparreboom 2014). Children could have also been cared for by neighbours, friends or relatives to allow the parents to go to work in poorer families (Rawson 2003a, 254).

The responsibilities of children varied enormously. Whereas most children had to complete individual chores around the house, the type and length of labour, education and training differed across social ranks. Slaves, for example, were only educated during their early years, and children of the aristocracy enjoyed longer and better education until they married or commenced public service (Hemelrijk 1999, 20; Harlow and Laurence 2002, 52; Mattingly 2008). Poor children possibly enjoyed some aspects of formal education but this may have been compromised by the need to learn a trade and contribute to the family income (Bradley 1994, 68; Harlow and Laurence 2002, 51-52; Rawson 2003a, 127, Joshel 2010, 150). This earlier transition of poorer children into their working lives would have affected their biological wellbeing, and may be discerned osteologically.

Children were regarded as lacking reason and therefore requiring strong mentoring and discipline (Gardner and Wiedemann 1991, 113-114). Yet, some sources attest that in some wealthy Roman families, very young children were considered a great pleasure (Gardner and Wiedemann 1991, 105; Laes 2010). Education and punishment were integral to Roman society (Laes 2011a, 140). Evans (1991, 169) stated that freeborn children were beaten and abused by their teachers to procure successful learning, yet there were some restrictions on physical chastisement of younger members of the household. Torture was not an acceptable means of punishment for young slaves, whereas beating was (Sigismund-Nielsen 2007, 53). Whipping of children was not unheard of, however the severity and frequency of these beatings are difficult to gauge (Laes 2011a, 142). Tolerating high levels of violence may have come natural to the Romans as a society sustained by warfare and fascinated by gladiatorial entertainment (Gardner and Wiedemann 1991, 113-114). Harlow et al. (2007, 8) commented on the often very bleak outlook on Roman childhood, sustained by authors such as DeMause (1974), who argue that childhood is a modern construct which was riddled with violence and sexual abuse in the past. However, from the 4th century AD new legislation dictated the punishment of a guardian who abused a child (Lefkowitz and Fant 2005, 100). If physical punishment was indeed the norm across the Roman world, children may have sustained injuries, some of which affecting the skeleton. Although fractures in immature bone heal quickly, these may still be found in the osteological record if the injury occurred shortly or immediately before death, or alternatively resulted in permanent morphological or functional changes to the affected element.

3.2.2. Stages in the Roman life course

Romans recorded chronological age as well as life spans, and commemorated ages that signified a transition in the child's life (Harlow and Laurence 2002, 149; Laes 2007, 29-30). Initially after birth, the infant needed to be welcomed into the family by the *paterfamilias*. A newborn was not to be named during the first week until the *dies lustricus,* with girls receiving a name on the 8th day after birth and boys on the 9th (McWilliam 2001, 78; Harlow and Laurence 2002, 39; D'Ambra 2007, 88). Prior to the ritual of naming, Roman society may have regarded the newborn as socially non-existent (Laes 2011a, 66). Harlow and Laurence (2002, 36-37) claim that there is no Latin equivalent for 'baby', which might signify this hazardous stage in the life course of children. This liminal state of being would have affected their treatment in life as well as in death, resulting in distinct funerary rites which have also been observed in other provinces such as Gaul and Germany (Derks 2014; Gowland et al. 2014; Millett and Gowland 2015).

Swaddling, which was seen as one of the initial steps in the socialisation of a child, ceased between day 40 and day 60 after birth , as advised by Soranus (II 42[111]) (Temkin 1991, 114-115). Subsequently, the 1st birthday marked increased legal privileges for the parents, which may have influenced how children were treated in both life and death (Mander 2013). In the funerary iconography and epigraphy of children, the ages of five and seven years receive emphasis (Mander 2013). Aged five a slave child could be sold and commenced work, and the period of *infantia* ceased aged seven years old. Up until the age of seven years, children were referred to as *infans*, which translates to 'not speaking' or 'no speech', likely to indicate their voiceless social status (Harlow and Laurence 2002, 37). From then on, children were required to partake in the family's private and public engagements, boys especially had to fulfil educational duties outside the *domus.* Harlow and Laurence (2002, 37) linked this transformation with loss of the deciduous dentition as a biological milestone, also included in the description of the Hippocratic Ages of Man (Table 3.1). An increasingly public life would have exposed these children to a higher risk of accidents, injuries and pathogens.

Adulthood commenced at different ages for Roman boys and girls and brought a very distinct set of responsibilities, bearing in mind that these are transitions in the life course of children of the elite. Once girls reached marital age from 14 years old, their transition from girl to virgin was closely guarded in preparation for the shift to mother and wife (Harlow and Laurence 2002, 56-57). Boys however had to don the *toga virilis* by 17 years old, which also allowed enlisting for military service. Further training and education in order to overcome puberty, which was thought to last until the early twenties, was required to form a morally upright citizen (Harlow and Laurence 2002, 65-67). At 18 years old, men could pursue the role of *equites*, which placed them in the social class of horsemen and knights, whereas at 25 years old, men were released from guardianship and possessed the minimum age to engage in political responsibilities (Nathan 2000, 133; Laes 2007, 30, Laurence 2010).

Table 3.1. The Hippocratic ages in children

Chronological age	**Description/ terminology**	**Biological milestones**
0-7 years	Small child	Teething
7-14 years	Child	First facial hair
14-21 years	Teenager	Full beard

(from Laes 2011a, 89)

3.2.3. Childcare practices

Soranus advised on adequate care for the newborn in the *Gynaecology* (Temkin 1991; Dunn 1995). It is believed that the practices described in the *Gynaecology* were firmly established in Rome from the 2nd century AD onwards. It remains to be established whether his works were applicable to the lower classes as it is generally still largely unclear how widespread medical care was in Rome itself, let alone the Empire as a whole (Jackson 1988; Dunn 1995; Allason-Jones 1999). The poor and peoples of the provinces may not have had access to medical personnel, wet nurses or the ability to read and follow medical literature.

3.2.3.1. Wet nursing and early infant feeding practices

Wet nursing was common practice in Rome, although physicians such as Soranus were aware of the benefits of the biological mother breastfeeding (Bradley 1986, 201; Dasen 2010). Usually wet nurses were slave or freeborn women of the lower social classes who lived with the family they were working for (Joshel 1986; Dasen 2010). Soranus (II 19[88]-20[89]) recommended a woman between the ages of 20-40 years who has given birth at least twice. She should also exhibit a range of physical attributes, such as a good complexion and sound health, alongside personality traits such as cleanliness, self-control and good virtue (Temkin 1991, 90-94). Wet nurses were not just concerned with suckling the infant but all other duties of early childcare until weaning was complete, including swaddling, bathing, massaging, laying the infant to sleep and supplementary feeding (Temkin 1991; Sparreboom 2014) (Fig. 3.1). Wet nurses frequently shared the same bed as the infant and pre-masticated food (Bradley 1986, 219). The latter promotes the transmission of infections, such as caries or even tuberculosis (Gussy et al. 2006; Marais 2011), whereas the former may increase the risk for Sudden Infant Death Syndrome or a fatal accident (McKenna and McDade 2005). In fact, Soranus (II 46[115]) labels bread pre-masticated by the wet nurse as “harmful”, and discourages the practice (Temkin 1991, 117-118). However, the fact that he warns of it, does suggest that pre-mastication was not uncommon.

In the *Gynaecology,* Soranus (II 17[86] – 18[87]) insisted on starving the baby for the first two days postpartum, followed by an introduction of boiled honey (Temkin 1991, 88-90). Not only will starvation harm the child, but the bacteria *Clostridium botulinum* in honey can actually be fatal by causing infant botulism (Nevas et al. 2002). Soranus recommended boiled honey, and the bacteria growing out of the spores of *Clostridium botulinum* which produce toxins are in fact destroyed by boiling. However, the spored themselves are heat resistant and when ingested by infants can colonise the gut and germinate into bacteria that release toxins (WHO 2013). Babies are initially constipated, then suffer from dysphagia and increasing neuromuscular paralysis. Ultimately botulism results in death by causing respiratory arrest (Arnon 1980; Aureli et al. 1986). Colostrum was to be avoided, hence why a wet nurse should have suckled other children before. When the biological mother was breastfeeding, colostrum was deemed unsuitable for 20 days postpartum. If no wet nurse was to hand during that period, the newborn was to be fed on boiled honey and goats’ milk for three days following the two day starvation period (Temkin 1991, 88-90). Colostrum, which is a term to describe the early breastmilk within the first week postpartum, is rich in immunoglobulins and antibodies that aid in the immunisation of the newborn against the bacteria and viruses of its new environment. Colostrum is generally richer in nutrients than mature or transitional breastmilk, supplying the newborn with the nutrition it needs to flourish. The laxative effects of this early type of breastmilk also allow the baby to pass meconium and stimulate bowel function, therefore decreasing the likelihood for jaundice (Goldblum et al. 1975; Ogra et al. 1977; Swisher and Lauwers 2011, 188-189). It is also important to consider the health implications of animal milk for the newborn. Whereas breastmilk contains antibodies and stimulates the growth of healthy and balanced intestinal bacteria, the proteins within cows' and goats' milk cannot be tolerated by the developing gut flora (Tomas 2009). By following Soranus' recommendations and feeding the newborn goats' milk, diarrheal disease may result which promotes malnutrition, which in turn increases the infant's risk for infection (McDade and Worthman 1998; Fewtrell et al. 2007). This risk may have been further exacerbated if the infant was exclusively fed on animal milk (from cows, sheep or goats) when breastmilk was unavailable (Fildes 1986, 35; Stevens et al. 2009).

Figure 3.1. Iconographic representation of the wet nurse, left Musée Gaumais à Virton, right Musée archéologique de Saintes (from Coulon 2004, 54)

3.2.3.2. Swaddling

Before swaddling, Soranus (II 13[82]) specified sprinkling the newborn with salt and washing the baby in lukewarm water (Temkin 1991, 83-84). Every part of the newborn was to be moulded and swaddled according to its natural shape, taking care of any swellings or misalignments. The bandages were to be made of soft and clean wool. Finally the entire infant was wrapped in a broader dressing with its head covered separately (Temkin 1991, 84-87)

(Fig. 3.2). Swaddling needed to be repeated several times a day and the infant is caused severe discomfort if swaddled incorrectly or too tightly (Joshel 1986). The infant was supposed to be unswaddled from day 40 (Temkin 1991, 114-115). Infants dying before the 40th day were frequently buried in the walls of houses rather than cemeteries, which may be a reflection of not having survived the first stage of the socialisation process (McWilliam 2001, 75-76). Laes (2011a, 68-69) also remarked on the 40 day feast for babies which took place in Roman Egypt, as part of a baby's social birth.

An idiosyncratic approach was advocated which favours gradual removal of the wrappings once the body of the infant was deemed sufficiently "firm" (Temkin 1991, 114-115). As suggested by Lewis (2010), swaddling may lead to rickets and subsequently rib fractures by limiting the skin's exposure to sunlight and exerting pressure on the infant's thorax and generally weakened bone structure. However, recent anthropological and medical research in modern populations has attested that swaddling only has a marginal impact on vitamin D deficiency and mainly promotes child wellbeing (Urnaa et al. 2006; van Sleuwen et al. 2007). However there are examples in the Classical literature which describe leaving the swaddled infant in a darkened room for prolonged periods which could cause rickets (Laes 2011a, 72). Equally, neglecting to wash the infant and changing the dressing are unhygienic. Yet, these shortcomings for infant health would ensue due to neglect, rather than swaddling per se. After all, swaddling is generally considered a beneficial practice, as infants exhibit better sleep and experience a lower risk for Sudden Infant Death Syndrome (Gerard et al. 2002; Franco et al. 2005).

Figure 3.2. Funerary depiction of a swaddled infant, Musée de Metz (from Coulon 2004, 45)

3.2.3.3. Weaning

Galen's writings and Soranus' *Gynaecology*, both dating to the 2nd century AD, recommend the introduction of supplementary foods from about six months old when the infant's body was deemed "firm" (Fildes 1986; Temkin 1991, 117). Weaning was to be complete at around 2-3 years old, a practice that has been supported by isotopic analysis of non-adult bone in both Italy and *Britannia* (Fildes 1986; Fuller et al. 2006a; Prowse et al. 2008; Prowse 2011; Nehlich et al. 2011; Redfern et al. 2012; Powell et al. 2014). A recent study on the weaning process in Roman London affirmed the introduction of solid foods from six months old, but attested complete cessation of breastfeeding by four years old, rather than 2-3 years (Powell et al. 2014). Powell et al. (2014) also suggested regional differences in maternal diet during pregnancy and lactation. Marine foods were frequently consumed by mothers at Isola Sacra, whereas women in London may have followed a specific restricted diet (Prowse et al. 2008; Powell et al. 2014). A weaning diet mainly consisting of C3 cereals has been isotopically validated (Powell et al. 2014) and textural sources describe the Roman weaning diet as consisting of cereal foods, such as porridge, or bread mixed with milk, wine or honey, soup or eggs. The infant was to be appropriately hydrated with either milk, or water and attenuated wine through the bottle (Temkin 1991, 117-119; Garnsey 1999). Once the deciduous dentition started to erupt through the gums at around 18 months-2 years old, additional solid foods should be introduced to take the infant swiftly off the breast (Temkin 1991, 114-119; Rawson 2003a, 126). Historic sources from the Republican period attest the use of feeding vessels for bottle-feeding, some women known as *assae nutrices* may have even specialised in artificial feeding, and Soranus remarks on artificial nipples to administer water or wine (Rosenthal 1936; Temkin 1991). Dated to the early 6th century, Muscio's *Gynaecia*, which relies heavily on Soranus' *Gynaecology*, describes glass vessel reminiscent of a nipple (*titina* or *ubuppa*) which were to be used for supplementary feeding (Rosenthal 1936; Fischer 1987). Finds of samian, glass, fine or coarse ware vessels with handles and spouts, believed to have served as infant feeding bottles, have been reported on the continent, in a 1st century AD burial at Colchester, and in Roman London (Fildes 1981, 1986; Eckardt 1999). If these vessels were indeed used for infant feeding, we also have to consider hygienic shortfalls due to unsatisfactory sterilisation of these bottles or contamination of the liquids within them which may have further prompted infection in the child (Quigley et al. 2006). However, we cannot be certain whether these were used for infant feeding at all, supplementing breastfeeding or exclusive bottle-feeding (Sparreboom 2014). A comprehensive study of these vessels is lacking as of yet, but it would be of great interest to investigate how widespread they were in the Roman world and what their specific purpose was.

Fildes (1986, 81) suggested that infants and young children will have suffered from diarrhoea and malnutrition based on the transitional feeding and weaning practices suggested by Soranus. The recommended diet as stipulated in the *Gynaecology* does indeed lack variety regarding its nutritional value, which may have prompted mal- or undernutrition, which in turn increases the risk for diarrhoeal disease and infection. This results in a vicious circle, known as the 'weanling's dilemma', where diarrhoea, malnutrition and infection are cause to, and effect of one another (McDade and Worthman 1998; Fewtrell et al. 2007). Not only does this cause immediate illness in the weanling, but also has long-term effects on health and growth (Dewey and Mayers 2011). The struggle of these young children may be visible as cribra orbitalia and porotic hyperostosis indicating anaemia, or as Harris lines or enamel hypoplasia as witnesses to growth disruptions. Elevated mortality may also be observed, alongside nutritional deficiencies.

3.2.4. Play

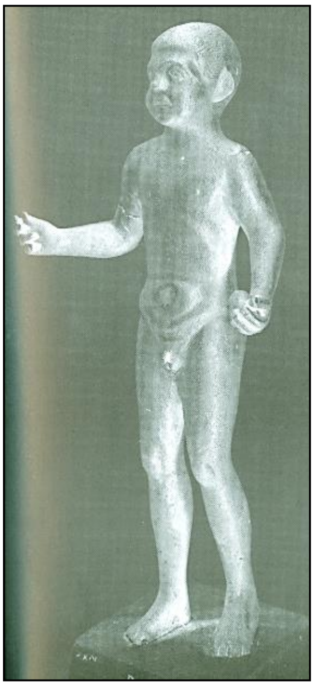
In Rome, it was mainly the nurses or childminders and the *paedagogus* that were concerned with the supervision of children at play, as parents of the elite were only sporadically involved in bonding with their children over play (Gardner and Wiedemann 1991, 104; Harlow and Laurence 2002, 43, 46; Rawson 2003a, 126-127; Laes 2011a, 115). The iconographic and literary depictions of young children at play are recognised but not widespread (Harlow and Laurence 2002, 47-50; Laes 2004). Rawson (2003a, 128-130) mentioned a range of toys for children such as rattles, dolls and a variety of carts to promote walking in toddlers (Fig. 3.3). We also have to bear in mind how the attainment of developmental milestones in young children affected their ability to engage in play, and therefore with other children, adults and the environment (Table 3.2).

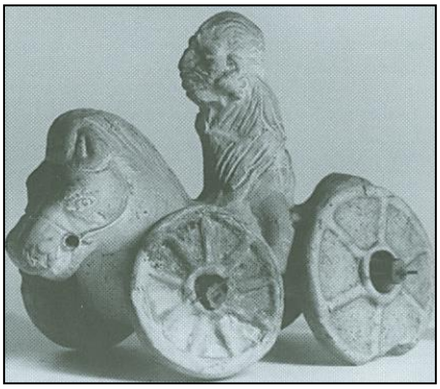
Mander (2013, 37-48) identified children in funerary depictions, including slaves, playing with birds or dogs (Fig. 3.3). Ball games, gambling, fishing, swimming and keeping pets were also popular among children of the elite (Evans 1991, 166-168) (Fig. 3.3). Laes (2004) discussed accidental child deaths in Rome by analysing inscriptions, literary and iconographic sources. These affected especially boys whilst playing outside the house, climbing trees and playing by wells and rivers (Laes 2004, 163-167). If children in Roman Britain exhibited similar behaviours, increasing interactions with others and venturing outside of the domestic sphere would have posed certain risks, including accidents and injuries, infections and even accidental deaths by drowning or falling.

Table 3.2. Developmental milestones of fundamental motor patterns

Developmental milestone	**Attainment age**
Roll to supine and roll to prone	By 6 months
Crawl on stomach	By 9 months
Sit up	By 12 months
Stand momentarily	By 16 months
Walk alone	By 16 months
Run, walk backwards, use stairs	By 24 months
Run, jump, climb objects, balance on one foot, confident in using stairs	By 36 months

(adapted from Sheridan 1991 and Malina 2004)

a, 

b, 

c, 

Figure 3.3. Children at play. a, Statuette of a boy holding a ball, Musée Lorrain de Nancy (from Coulon 2004, 87); b, Figurine of a horse and rider, possible toy, Römisch-Germanisches Museum Köln (from Coulon 2004, 108); c, Funerary stela of Clarus with a bird, Villa Zeri (from Mander 2013, 39)

3.2.5. Dying young

Laes (2007, 29) stated that *mors immatura* was a dreaded fate as the child had perished before having achieved the virtues of adulthood. Grieving for a child was meant to be proportionate to the child's age, with older children mourned with greater intensity (Evans 1991, 175; McWilliam 2001, 78; Mander 2013, 19). Based on demographic models, it is estimated that among the upper classes, one third of children died during the first year of life and nearly half of all children died before the age of 10 years (Bradley 2005, 69). In order for the Romans to sustain population numbers, fertility had to be high, and estimates range from an average of 5-6 births per adult woman. Once a child had lived until the age of five years old however, the average life expectancy rose from 25 up to 45 years (Parkin 1992, 91-96). Rawson (2003a, 116) suggested a high frequency of miscarriages, although it is difficult to pinpoint numbers. As a comparison, the NHS estimates that at least 12% of pregnancies in Britain today end in miscarriage (NHS 2011). It has to be borne in mind that this number may have been even higher in a pre-industrial society. Roman midwives were concerned with labour, and a physician was only consulted during major complications that required embryotomy, for example (Temkin 1991, 189-192). Not every birth was assisted, especially in the lower social classes or in more remote rural areas. There were no dedicated facilities for women to give birth, and we cannot rule out that babies may have been delivered elsewhere such as in the workplace (Rawson 2003a, 121; Laes 2011a, 208). Based on the literary evidence, it is impossible to pinpoint the exact reasons why babies died in Roman Britain. However, by studying neonatal and post-neonatal mortality, it is possible to explore the endogenous and exogenous factors that affected the survival of infants in Roman Britain.

Roman medical practice was flawed by the inability to deal with infectious disease (Bradley 2005, 69, 72; Gourevitch 2010). However, physicians were aware of child-specific illnesses and remedies, and there is an extensive body of Roman medical literature to cure sick children (Rawson 1991, 15; Bradley 2005, 70-72). Laes (2008; 2011b; 2011c) discussed the evidence of disability in Antiquity and the care given to disabled or handicapped individuals. Contrary to popular belief, considerable medical and personal care was invested in disabled and sick children. Some disabilities may have gone unnoticed for a certain period of time or manifested later in life due to a developmental rather than congenital origin, or accidents and injury (Laes 2008; Southwell-Wright 2014). Children with disabilities were cared for by their families, although they may have been hidden from public life (Laes 2008; 2011b; 2011c). Examples include the deaf-mute painter Quintus Pedius born into the senatorial order during the 1st century AD, now believed to have suffered from Little's disease caused by a cerebral lesion at birth (Laes 2008). The archaeological record has produced several examples of disability in childhood in Roman Britain, including deaf(-mute)ness (Lewis pers. comm.; Farwell and Molleson 1993, 265), hydrocephalus (Duhig 1993; Brothwell et al. 2000, 234; Roberts and Cox 2003, 115), clubfoot (Roberts et al. 2004), premature cranial synostosis (Mumford 2002) and birth trauma (Boylston and Roberts 2004, 343), clearly demonstrating that these children were cared for by their parents and/or community.

Working and living conditions, in both urban and rural environments were hazardous for children. There are examples in the literature of young children sustaining fatal injuries tending to animals (Bradley 1991; Bradley 1994; Laes 2004). The urban environment was overcrowded with unstable houses and increased risk of fire (Laes 2004). Public and industrious life brought about hectic and dangerous traffic which also proved hazardous for children. The quality of life in Roman towns would have been unbearable by modern standards of hygiene (Scheidel 2006). Sanitary shortfalls apply to the feeding vessels used as they certainly will not have been sterilised to a standard we deem acceptable today, to public latrines and baths as places for socialising (Scobie 1986).

3.3. WRITTEN AND ARCHAEOLOGICAL EVIDENCE FOR DIET AND ORAL HEALTH

Since the current study encompasses a discussion of dental disease patterns in Romano-British children, it is important to be aware of both diet and dental health in Roman Britain and Rome itself. There is written and archaeological evidence for diet, dental care and oral hygiene in the Roman period. The Roman medical writer Celsus in his works *De Medicina* (VI. 8.9. and VII. 10.12.) described toothache as one of the worst torments to mankind, and suggested analgesic treatments involving opium, saffron or pepper, or even more drastic methods such as tooth extraction (Spencer 1938a,b). Carious lesions may have been cleaned using spoon-shaped instruments (Milne 1907). Fejerskov et al. (2012) discussed a find of 86 teeth recovered from a channel leading to a cloaca in the *Forum Romanum* in Rome, dating to the 1st century AD. The sample was mainly composed of permanent molars, and all teeth displayed large cavities owing to caries. The authors concluded on these being direct evidence for dental care in ancient Rome, where the extraction of decayed teeth and some surgical removal of carious cavities was undertaken by skilled personnel. The presence of two deciduous molars in the sample also demonstrates that dental care was available to children. However, access to dental care was mediated by status and locale, where the poor and those living in more remote areas were less likely to receive dental treatment (Fejerskov et al. 2012). The works of Hippocrates, Celsus, Pliny and Scribonius Largus show that upper class Romans were very concerned with preserving clean teeth and fresh breath (Fischman 1997).

Mouth-rinses of salt water, or salt, alum and vinegar were in use to prevent bad breath. Teeth were kept clean by washing and rubbing them with wool and using dentrifrice. These were made of myrrh, roseleaves and gallnuts, or ground oyster and eggshells, alternatively also burnt antlers or hare's or rodents' heads (Bennion 1986; Fischman 1997). Toothpicks were available to everyone, either provided after dinner in the more affluent households mainly made from organic materials, or simply by chewing splinters of wood (Jackson 1988, 120).

One of the earliest studies to explore deciduous dental health in Roman Britain was by Moore and Corbett (1973) who reviewed the distribution of caries in eight non-adults (N=212 teeth). Nine deciduous molars were affected by caries, which equals a true prevalence rate of 4.2% (number of carious teeth out of the total of observed teeth). Although the sample was small, the authors argued that Romano-British towns and military sites would have had access to finely ground wheat, honey and imported fruits especially to the upper classes, which would have contributed to the development of carious lesions in children. O'Sullivan et al. (1993) recorded caries in 66 children from several Romano-British sites across southern Britain, and recorded a true prevalence rate of 16% (n=60/364 deciduous molars), threefold the rate in the earlier prehistoric samples of 5.0%. In 1981, Whittaker and colleagues examined dental caries in 84 non-adults (up to 16 years old) from Poundbury Camp, Dorchester. Although no distinction between deciduous and permanent teeth was made, a crude prevalence rate for carious lesions of 15.8% (number of individuals with caries out of the total of individuals with dentitions observed) was reported in the children. The rise in deciduous caries in the Roman sample also corresponds to a rise in carious lesions in permanent molars, which is suggestive of a change in diet for the population as a whole rather than just the children. Redfern et al. (2012) also compared dental health and metabolic disease in a total of 200 non-adults from late Iron Age and Romano-British Dorset. No deciduous caries was found in the late Iron Age cohort, but four non-adults were affected by carious lesions in the permanent dentition (1.4% crude prevalence rate). In the Romano-British sample (which included some individuals from Poundbury Camp), deciduous caries was observed in one individual (0.3%), and in seven individuals with permanent teeth affected (1.5%), indicating a slight rise in the crude prevalence of caries from the Iron Age to Roman period in Dorset.

Prowse et al. (2008) studied dental evidence for feeding practices and childhood diet in 78 non-adults aged 1-12 years old from the 1st-3rd century AD necropolis at Isola Sacra of Portus. Both periapical lesions and antemortem tooth loss were low with one and two individuals affected respectively. The true prevalence rate for caries was 3.8%, and mainly confined to the deciduous molars. The sample displayed a decrease in caries as the children grew older, with a fall in the 10-12 year old age group due to exfoliation of the deciduous dentition and eruption of the permanent teeth. No caries was reported in children under the age of two years, which the authors attributed to the short timeframe teeth would have been exposed to the oral environment after eruption (Prowse et al. 2008). Both calculus and caries were present in non-adults aged 2.5 years and older which suggests cariogenic foods in the weaning period and in later childhood, probably in the form of carbohydrates and soft foods available in the transitional diet (Prowse et al. 2008; Prowse 2011). Although we are presented with caries rates from Roman Britain and Rome itself, comparison between the studies is hampered by how these rates are presented, for example as true versus crude prevalence rates, or discussing deciduous or permanent teeth in isolation.

Information on the adult Roman diet mainly comes from sources that cite Apicius' collection of recipes, a sourcebook for elaborate sweet treats, meat and fish dishes intended for the elite (Grocock and Grainger 2006). Apicius is not the only Roman cookery book, but merely the one which has been translated most readily and adapted to fit modern tastes, and therefore still remains in circulation today (Alcock 2010). Other prominent works such as Pliny the Elder's *Naturalis Historia* or Galen's medical writings make reference to food and drink. Similar to Apicius, they reflect Mediterranean practices of the literate upper classes in the 1st and 2nd centuries AD. It remains unknown how much of it bears relevance for diet in Roman Britain during the 3rd and 4th centuries AD, especially considering eating and drinking in childhood (Cool 2006).

Archaeological investigations of foodways and diet in Roman Britain have yielded more fruitful insight. More advanced farming and plant cultivation techniques, alongside larger scale animal breeding as a result of the Roman occupation would have ensured food supply for the army and non-producing urban population, whilst also putting increasing demands on the producing agricultural population (Mattingly 1997, 210; Dobney 2001, 35-36; Taylor 2001b, 54; Pitts and Griffin 2012; McCarthy 2013, 62). It has been demonstrated previously that intensification in agriculture may yield initial changes in health, both positive and negative (Clark et al. 2014). Cereal products such as bread, cakes and porridge would have been the staple foods in Roman Britain, although these may have varied in their forms across the social and geographical strata (Cool 2006, 69-70). Evidence for imported Roman delicacies has been found in major urban settlements, perhaps indicating an acquisition of Roman tastes in the urban centres (Jones 2004). Sugar would have only been available in the form of fructose from fruits, fruit juices and the sweeteners honey and *defrutum*, or glucose in the carbohydrates consumed (Moore and Corbett 1973; Bowman and Thomas 1994, 135; Cool 2006, 67-68; Bogdanov et al. 2008; Nassar et al. 2012). Studies by King (1984; 1999; 2001) and Cummings (2009) have demonstrated that the consumption of, and access to, meat was dependent on site type and status: meat was not an everyday staple for the majority of the population, and would have been primarily eaten by higher status individuals. Differences in butchery practices evident on cattle bone assemblages from urban and rural settlements suggest more specialised large-scale and intensive carcass processing in the towns (Maltby 1989). Marine and freshwater fish became increasingly fashionable, probably as a result of following Roman tastes, which again would have applied more to higher status groups (Locker 2007). Isotopic studies on human bones (Richards et al. 1998; Redfern et al. 2010; Cheung et al. 2012; Müldner 2013) and archaeobotany (van der Veen et al. 2008) have revealed temporal, cultural, social and gender differences in the consumption of terrestrial, plant and aquatic foods, not just on the inter-site, but also the intra-site level. Overall, children enjoyed more marine foods, and diet became more varied for the inhabitants of the towns (Redfern et al. 2010; Müldner 2013). At Roman Gloucester, it has also been demonstrated that marine and freshwater foods were primarily consumed in the urban environment rather than the surrounding villages, and that the male and female diet may have differed (Cheung et al. 2012). Richard et al.'s (1998) study on Poundbury Camp showed that animal protein and marine foods were only available to some (probably higher status individuals), rather than the population as a whole. To the benefit of Roman Britons, a variety of new plant foods were introduced following the Roman conquest, improving the nutritional value of the Romano-British diet. Plant foods were largely accessible to both higher and lower status individuals, and eaten in both town and country, however at varying frequencies. Although some areas of Britain, such as the southwest, differed and access to new Roman plant foods was more restricted, or perhaps opposed (van der Veen et al. 2008). Dietary variation in Roman Britain has mainly been validated using adult skeletal materials, and no information on non-adult diet is obtainable once children were weaned. However, if diet was influenced by location and status, children would have also been subjected to differential food allocation. It is therefore anticipated that dental disease rates will differ across Roman Britain, depending on urban and rural site types, or high versus low status settlements.

3.4. THE INFANTICIDE DEBATE

According to Classical sources, parents could resort to exposure, with the final decision over a child's right to live and grow up in the family made by the father, or *paterfamilias*. Both infanticide and exposure may have been practised in families too poor to provide for another child or too rich to risk fragmentation of the estate. In Antiquity, illness or disability in newborn babies may have also driven parents to rid themselves of their children. The 1st century AD philosopher Seneca referred to children born with a disability as monstrous and weak, and Aristotle during the 4th century BC demanded a law to be instated which prevented parents from rearing their handicapped children (Germain 1975, 232-234; Grubbs 2013, 88). However not all parents chose to dispose of their disabled children shortly after birth, and other disabilities may not have become obvious or only developed later in childhood, and parents therefore continued to raise these children (Scott 2001; Allély 2004, 91-95; Laes 2013; Southwell-Wright 2014).

It is vital to differentiate between exposure and infanticide, a distinction that some authors in the older literature fail to undertake (Bennett 1923; Engels 1980; Harris 1982; Shaw 2001; Corbier 2001, 69). Death was not a given for exposed infants and Rome was rife with well-known places for foundlings where these babies were placed in daylight. Abandoned infants could be collected by slave traders or families wishing to adopt. Parents who had abandoned an infant were then presented with the option of claiming their child back later in life (Fildes 1988, 4; Dupont 1989, 220; Parkin 1992, 95; Corbier 2001, 62-69; Joshel 2010, 56; Laes 2011a, 201). It remains largely unclear if these practices were adopted by the native populations in the provinces. For example, classical sources state that the Jewish community openly opposed infanticide (Garnsey and Saller 1987, 138; Gowland et al. 2014).

Infanticide may not always have been intentional. It can be argued that the child rearing practices and certain aspects of early infant care, as described above, have led to what might be described as accidental or unintentional infanticide. Other means of regulating family size in Rome, such as contraception and abortion would have resulted in the death of a foetus or newborn, which can be archaeologically visible. Contraception and abortion were widely practised and established means for controlling family size, especially among the elite (Hopkins 1965; Rawson 2003a, 114; Bujalkova 2007). Roman medical practitioners were in dispute about conception and the length of gestation (Dasen 2013). Processes that according to modern definitions would be regarded as abortions may have been viewed as contraception or purely a means to bring about menstruation since the early stages of pregnancy might not have been recognised (Dowsin 2000, 23; Bujalkova 2007). Soranus advised on a range of contraceptive substances, whereas others believed in ‘magical’ and mythical means (Dowsin 2000, 11; Frankfurter 2006; Todman 2007). Women wanting to avoid pregnancy were to use spermicidal substances such as alum stick, brine or vinegar and hinder sperm to enter the uterus with sticky matter such as olive oil (Dowsin 2000, 12). Additionally, sneezing and squatting immediately after intercourse were recommended, which informs on some of the naivety surrounding obstetrics in Rome (Hopkins 1965). The contraceptive effect of prolonged lactation might have been welcomed by the poor women choosing to work as wet nurses, both to earn money and to avoid bearing more children themselves (Fildes 1988, 8; Hrdy 1992; Sparreboom 2014).

In congruence with the Hippocratic Oath, no abortifacient should be given, although abortion was practised openly (Bujalkova 2007). The embryo was considered part of the woman’s bowels and the foetus was therefore not human. Abortion was only a crime when the father had been circumvented in the decision making process (Rawson 2003a, 114-115; Bujalkova 2007). Soranus offered two distinct methods to induce abortion. The medicinal approach involved the ingestion or vaginal introduction of drugs, potions or ointments, often similar to those used for contraception. The physical method required little nutrition, leaping, shaking, excessive bathing, strenuous exercise or manual labour to facilitate expulsion. Enemas, diuretics and venesection were also suggested. These caused purging of fluids which was thought to induce eradication of the foetus (Temkin 1991, 61-68; Dowsin 2000; Bujalkova 2007; Drife 2010). The high rates of miscarriages may have provided artificial proof for the effectiveness of contraceptives and abortifacients (Dowsin 2000, 17). Yet again, the inefficiency of these methods might have led to a high number of mechanical abortions undertaken by physicians as well as illegitimate backstreet practitioners (Hopkins 1965; D’Ambra 2007). It may have been more viable to deliver and abandon an infant rather than enduring surgical or mechanical procedures, and exposure may have subsequently been seen as a late form of abortion (Dowsin 2000, 33-42; Laurence 2005).

Embryotomy was relied on in cases of difficult births. Soranus (IV 3[55], IV 7[59]-12[64]) gave accounts of removal of the dead foetus in breach and other difficult positions, which resulted in decapitation, amputation or mutilation of the foetus before being extracted with hooks, posing a serious risk to the mother (Temkin 1991). To date, injuries indicative of embryotomy have been reported from two sites in Roman Britain. Cut marks throughout on a perinate at Poundbury Camp indicate dismemberment, which follows the procedure for embryotomy described by Soranus (Lewis pers. comm.; Molleson and Cox 1988; Roberts and Cox 2003, 160-161; Redfern and Gowland 2012). Cut marks on the right femur of a perinatal infant from Yewden Roman *villa* in Hambleden, Buckinghamshire, are also indicative of embryotomy being performed on a rural site (Mays et al. 2014). These finds indicate that Roman medical practice may have been followed in Roman Britain, although more cases are required to substantiate whether embryotomy was performed across the whole of the province or only on high status 'Romanised' sites.

There are several papers in the osteoarchaeological literature that argue for infanticide in Roman Britain (Mays 1993; 2003; Mays and Faerman 2001). These are based on the assumption that high perinatal mortality is artificially induced, and that modes of infant burial in Romano-British settlements are a means of disposal of unwanted dead babies rather than ritual behaviours of treatment in death (Carroll 2011). However, assemblages of infants and perinates within a confined burial space do not substantiate claims for deliberate killing and hasty disposal (Scott 1992). Scott (1997, 7-8) urged us to look beyond the sensationalist topic of infanticide, in order to discuss patterns in the ideological treatment of Romano-British infants in death. Naturally, infant and neonate mortality is high in any pre-industrial society, which most likely would have been the case in Roman Britain (Becker 1995; Scott 1999, 118). In the absence of modern medical care and hygiene, the newborn will have been exposed to greater risks, ultimately raising mortality (Kinaston et al. 2009). Coupled with differential burial rites for infants and perinates, such as clusters or intramural interment, and the probability of a ritual component, the evidence for infanticide as a means of family planning is increasingly diminishing (see Esmonde Cleary 2000; Scott 1992; 1999; Pearce 1999a,b, 2001a, 2013; Norman 2002; More 2009; Bonsall 2013a; Gowland et al. 2014; Southwell-Wright 2014; Millett and Gowland 2015). Gowland and Chamberlain (2002) reinforced this reasoning by pointing the potential bias introduced in infant long bone ageing based on regression formulae which will mimic the reference collection. The authors incorporated 396 infants from 19 different sites and various archaeological contexts. A Bayesian approach for the interpretation of the infant mortality age distribution revealed a mortality curve characteristic of the high rate of infant death in pre-industrial societies. Whereas Gowland and Chamberlain's (2002) work does not deny the presence of infanticide in Roman Britain, it nevertheless proves that it was not practised to an extent where it impacted on the natural mortality curve. Generally, a peak in infant mortality around and shortly after term should not dictate a diagnosis for the continuous practice of infanticide. Taking Classical, contextual archaeological as well as bioarchaeological information into account, Gowland et al. (2014) and Millett and Gowland (2015) suggested that, had any practice to limit family size been regularly followed in Roman Britain, it would have been exposure or abandonment. However, these practices remain archaeologically invisible. Intramural and clustered burial of infants are a result of differential burial rites which are specific to ages-at-death, and shaped by careful considerations of burial location by the grieving community (Moore 2009; Gowland et al. 2014). Proximity of the living and the dead is sought, often by interring infants in domestic contexts, possibly to maintain a mother-infant bond (Millett and Gowland 2015). This reasoning infers that great thought and care was invested into the burial of these infants who died as a result of both endogenous and exogenous factors of their respective biological and social environment, rather than being the victims of brutality.

3.5. APPROACHES TO SLAVERY AND FORCED LABOUR IN ROMAN BRITAIN

Slavery was widespread in Rome, and may have been followed in the provinces to a similar extent (MacMullen 1987; Mattingly 2008). The life course of slaves in Rome was considerably different to that of the free population. We cannot rule out an enslaved or oppressed part of society in Roman Britain, and therefore have to be aware of the everyday lived realities of slaves as discerned from the Classical literature. Among high-ranking families in Rome itself, slaves were considered part of the family, and may have received formal education, generous pay and eventually been granted freedom as a reward for years of devoted service (Dixon 1991; Saller 1994; Thompson 2006; Dasen and Spath 2010). However their treatment may have differed vastly, according to who their master was, and where they were forced to work. Slaves in the mines or on *villa* estates would have been forced to endure long hours of demanding physical labour and spatial constraints of the slave quarters (Joshel 2010). The modern preconception of rural slaves being predominantly male also has to be challenged. Female slaves were seen as a means of strengthening the bond of the servile classes to the farmland, and slave families were common (Barrow 1928, 152; Mouritsen 2011). According to Roman law slaves were not allowed to marry, however there was a certain degree of freedom within the legislation as family units could still be formed if permitted by the slave owner (Bradley 1984, 47-50; Joshel 2010). After all, children born as a result of these unions belonged to the household and were an asset to the estate (Barrow 1928, 153; Rawson 1966; Bradley 1984, 48, 51; Joshel 2010, 40; Laes 2011a, 158).

Slave children were usually traded as a mother-child unit, unless they had been foundlings that were put into slavery. Girls were subject to sale from the age of four years old, whereas boys were marketed from as young as age two. With the onset of puberty, children were officially separated from their mothers and sold as individuals (Bradley 1984, 53-56). According to the Classical literature and iconographic depictions on funerary monuments, slave children rarely had to work below the age of five years. By the age of 10 years every slave child would have been required to fulfil designated chores (Bradley 1991, 108-110; 1994, 68; Laes 2011a, 161; Mander 2013). Forced labour may have come in an additional form, not just for slaves per se, but also as a tied labour force on late Roman *villae*. Peasants who were bonded tenants were referred to as *coloni*, and were part of a system of landownership and taxation that is similar to later medieval feudalism or manorialism (MacMullen 1987; Whittaker 1987; Whittaker and Garnsey 1997).

Direct archaeological evidence for slavery, such as shackles, in Roman Britain is scarce, and this topic, especially concerning children, remains an understudied subject (Webster 2005). To date, only one writing tablet from London attest the sale of a slave girl (Tomlin 2003), and it is difficult to evaluate the applicability of one find to what may or may not be a sociocultural norm. Webster (2008, 2010) reasons that, based on slavery being commonplace throughout the Roman provinces, there are no grounds to suspect that forced labour and its implications, such as migration should not be seen in Roman Britain. If slaves were kept, these individuals may be detected in the osteological record.

Today, oppression and social inequality have measurable effects on health, and would have done so in the past (Farmer 2003; Maru and Farmer 2012; Crandall 2014). As an example for a past population, Kipple and King (1981) discussed the detrimental health effects suffered by the children of the African slave populations in North America. Although the sociocultural context differs, the study still gives insight into common childhood illnesses of those living in slavery, which we may expect to see in Roman Britain: rickets, and other dietary deficiencies, tetany, respiratory infections, premature and low birth weight babies born to mothers who themselves suffered from compromised health such as anaemia (Kipple and King 1981, 101). Additionally, higher infant mortality as a result of a shorter inter-birth interval and increased fertility are directly related to poverty within the enslaved population (Birdsall and Griffin 1988; Kipple and King 1981, 108; Scott and Duncan 1999a,b; 2000). Detecting exploitation as a form of violence therefore has to incorporate a nuanced approach that looks beyond the obvious skeletal signs of inter-personal violence and work-related injuries (Goodman et al. 1995; Klaus 2012). Ultimately, marginalisation and restricted access to resources will shape health outcomes, to which the growing child is most sensitive to, producing lifelong skeletal signatures (Martin et al. 1984; Walker 2001, 575; Klaus 2012).

However the slaves that were considered part of the family in distinguished households would have received similar treatment to other family members which would not have resulted in a differential health status (Thompson 2006). Yet the majority of slaves found themselves in an enterprise setting, and were forced to work under considerably harsher conditions from a young age. Labouring in agriculture, mining or other industrial sectors would have affected the skeletal health of these individuals (Laes 2011a). Pitts and Griffin (2012) and Redfern et al. (2015) have detected differential health signatures in rural settings which have alluded to a tied labour force on *villa* estates or other large elite estates, and it is of interest to see whether these patterns are obvious when considering non-adult remains in isolation.

3.6. SUMMARY

This chapter intends to provide a synthesis of the different avenues that have been utilised for exploring childhood in Roman Britain and in the city of Rome itself. Palaeopathological studies provide primary evidence for the childhood experience in Roman Britain. However, the focus of these studies is mainly urban, and certainly regional, which prevents from obtaining a holistic picture of growing up in Roman Britain. The written and iconographic Classical sources give a rich appraisal of what life would have been like for children. Yet, we cannot be certain how relevant these descriptions were to those of low socioeconomic status, and most importantly to children growing up outside of Rome in a province at the fringes of the Empire, several centuries later. Despite these limitations, discarding the Classical evidence is unhelpful, as parallels in Roman and Romano-British child rearing practices have been isotopically and osteologically validated. Roman cultural influence was most certainly felt in *Britannia*. Based on previous palaeopathological studies, specific aspects of the 'typical Roman' childhood experience are anticipated in the osteological profiles of the non-adults discussed in forthcoming chapters of this thesis. When analysing the new non-adult skeletal data gathered for this study, many of these themes will be revisited. First in Chapter 4 for materials and methods, where osteological data from urban and rural settlements across Roman Britain was sought to provide a national overview. The methods are reflecting the palaeopathology of Romano-British non-adults observed previously, and are further based on anticipated health insults discerned from the Classical sources. The discussion of the results in Chapter 7 also incorporates both Classical and palaeopathological perspectives for contextualising some of the patterns of ill-health observed in children from different settlement types and age groups.

CHAPTER 4. MATERIALS AND METHODS

4.1. MATERIALS

4.1.1. Introduction

Sites were selected for inclusion in the study sample from a series of urban and rural settlement types (Fig. 4.1). Primary data was collected through the re-analysis of 15 previously published and unpublished sites. Additional secondary data was compiled for 13 sites from the grey literature, published skeletal reports and site archives to provide a broad dataset for Romano-British child health (see Tables 4.1 and 4.2). Secondary data was only included when it was available as a skeletal inventory or catalogue, detailing the age and palaeopathology of non-adults. With an increasing interest in non-adult bioarchaeology, recent publications provided an in-depth study of non-adult skeletons (e.g. Lankhills, Winchester by Booth et al. 2010, and recent publications on Poundbury Camp, Dorchester by Lewis 2010; 2011; 2012).

A wide spatial distribution of sites was sought. The study is restricted by the availability of skeletal remains from excavated sites which are concentrated on central and southern areas, and has a focus on major urban cemeteries, which is a common theme in Romano-British archaeology (Pearce 2008; 2010, 86; 2015) (Fig. 4.1). The cemeteries date from the 1st through to the 5th century AD, with the only few burials pre-dating the 3rd century AD.

Table 4.1. provides a breakdown of the sites accessed for skeletal data collection by the author, ordered by the size of the archive. The total rural sample (n=212) is smaller than both the major urban (n=391) and minor urban samples (n=349) due to issues associated with the excavation, curation and accessibility of skeletal remains from rural Romano-British sites. Skeletons from these contexts are sparse, often badly preserved and the minimum number of individuals is too small to warrant recording (N<10); other skeletal collections such as Frocester (Table 4.2.) have been reburied and cannot be accessed at the present time.

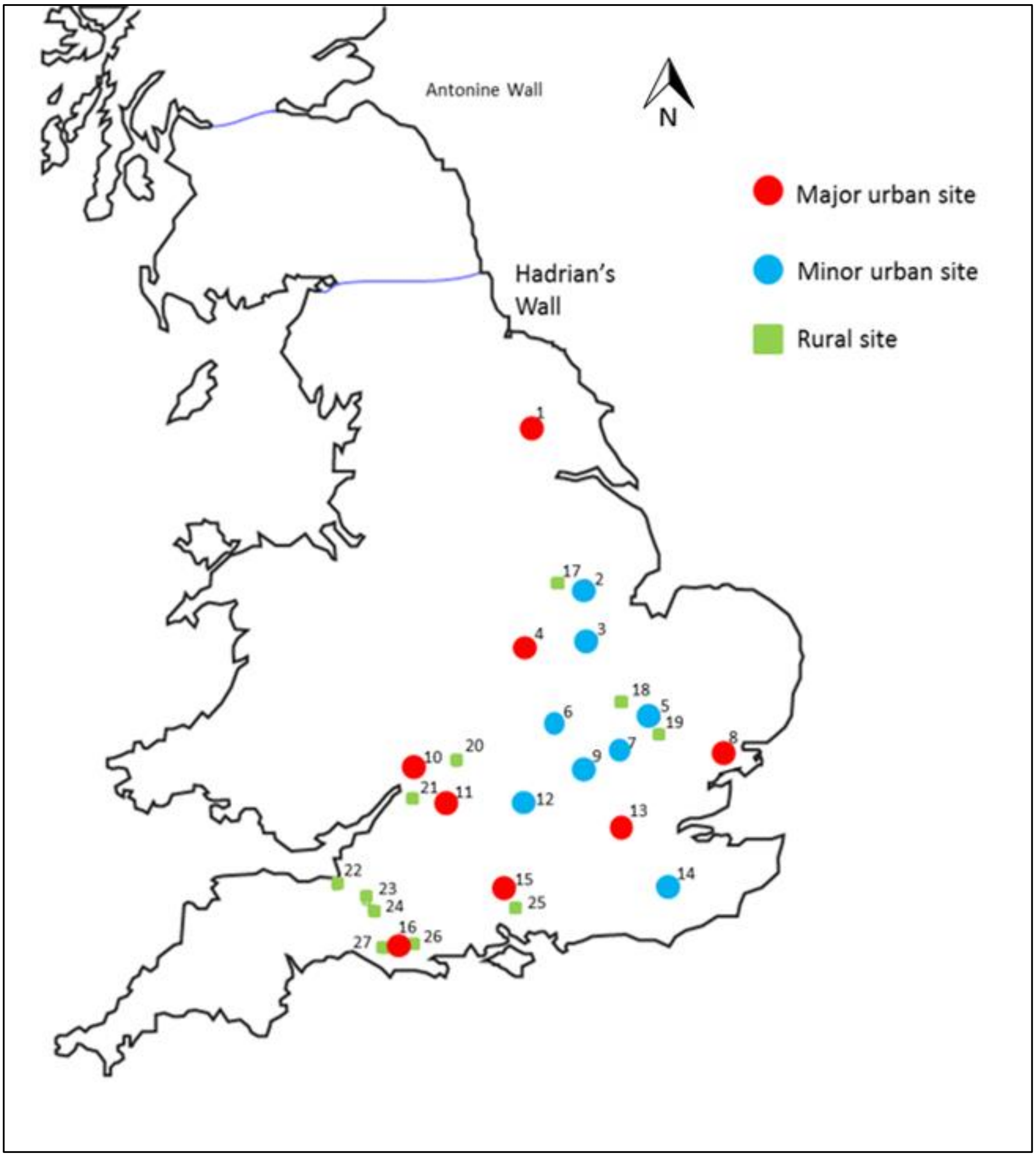


Figure 4.1. Location of sites; ***MAJOR URBAN*** *1. York 4. Leicester 8. Colchester 10. Gloucester 11. Cirencester 13. London 15. Winchester 16. Poundbury, Dorchester;* ***MINOR URBAN*** *2. Ancaster 3. Great Casterton 5. Chesterton 6. Ashton 7. Baldock 9. Dunstable 12. Queensford Farm/Mill 14. Springhead;* ***RURAL*** *17. Bantycock Mine 18. Watersmeet 19. Babraham Institute 20. Huntsman's Quarry 21. Frocester 22. Cannington 23. Bradley Hill 24. Catsgore 25. Owslebury 26. Dewlish 27. Dorchester-by-pass*

Table 4.1. Sites and numbers of individuals in the primary study sample

Site	Date (century AD)	N individuals	n non-adults reported (%)	n non-adults recorded	% non-adults recorded
MAJOR URBAN					
Butt Road, Colchester, Essex	4th-5th	700	121 (17.3)	109	15.6
Gloucester, Gloucestershire	2nd-4th	558	28 (5.0)	29	5.0
Bath Gate, Cirencester, Gloucestershire	4th	362	63 (17.4)	64	17.4
Trentholme Drive, York, North Yorkshire	3rd-4th	343	63 (18.4)	24	7.0
Winchester, Hampshire	1st-4th	329	111 (33.7)	166	50.5
Major urban N		2292	386 (16.8)	**392**	**17.1**
MINOR URBAN					
Ancaster, Lincolnshire	3rd-4th	327	84 (25.7)	81	24.8
Ashton, Northamptonshire	4th	297	100 (33.7)	60	20.2
Baldock, Hertfordshire	2nd-4th	>176	-	83	-
Queenford Farm/Mill, Oxfordshire	3rd-4th	160	58 (36.3)	60	37.5
Great Casterton, Rutland	3rd-4th	140	48 (34.3)	38	27.1
Dunstable, Bedfordshire	3rd-5th	112	30 (26.8)	27	24.1
Minor urban N		1212	320 (26.4)	**349**	**28.8**
RURAL					
Cannington, Somerset	3rd-4th	542	155 (28.6)	148	27.3
Bradley Hill, Somerset	4th-5th	55	35 (63.6)	29	52.7
Owslebury, Hampshire	1st-4th	49	16 (32.7)	16	32.7
Catsgore, Somerset	2nd-5th	26	23 (88.5)	19	73.1
Rural N		672	229 (34.1)	**212**	**31.5**
Total N				**953**	

% of total site sample

Table 4.2. Sites and numbers of individuals in the secondary data

Site	Date (century AD)	N individuals	n non-adults reported	% non-adults reported
MAJOR URBAN				
Poundbury Camp, Dorset	3rd-5th	796	364	45.7
Lankhills, Winchester, Hampshire	4th	313	67	21.4
Roman London	4th	173	50	28.9
Clarence Street, Leicester, Leicestershire	3rd-4th	92	13	14.1
Major urban N		1778	**494**	**27.8**
MINOR URBAN				
Springhead, Kent	1st-4th	104	82	78.8
Chesterton, Cambridgeshire	3rd-5th	57	9	15.8
Minor urban N		161	**91**	**56.5**
RURAL				
Watersmeet, Cambridgeshire	4th-5th	72	14	19.4
Frocester, Gloucestershire	3rd-5th	62	43	69.4
Babraham Institute, Cambridgeshire	2nd-4th	42	12	28.6
Dorchester-by-pass, Dorset	4th	27	9	33.3
Bantycock Mine, Nottinghamshire	2nd-4th	24	7	29.2
Huntsman's Quarry, Gloucestershire	2nd-3rd	23	12	52.2
Dewlish *villa*, Dorset	4th	8	8	100
Rural N		258	**105**	**40.7**
Total N			**690**	

% of total site sample

4.1.2. Defining urban and rural settlement types

There is a growing awareness of the difficulty of classifying Romano-British urbanism (see Brown 1995; Millett 1999; 2001; 2005; Burnham et al. 2001; Jones 2004; Pearce 2008; Holbrook 2015); and previous discussion and interpretation focussed on the archaeological evidence of defence structures and the function of towns as seats of power (Mattingly 1997, 210-213). Power in Roman Britain was not exclusively urban, as the elite often resided in the countryside or a town's immediate hinterland (Parkins 1997, 83; Pitts and Perring 2006). Although the large towns are regarded as cultural islands of Roman lifeways and material culture, it is likely that their sociocultural status and ideals were of little relevance to those living in their hinterland (James 2001, 203; White and Gaffney 2003, 231). The 'Roman-ness' of *Britannia* and its larger towns still remains in question (James 2001, 203-204). Pitts (2008) suggested that the spread of material culture does not necessarily imply the transfer of cultural values, raising the question of how 'Romanised' Romano-British town dwellers actually were. Millett (2001, 60) also remarked on the issues associated with generalisation of Romano-British urbanism based on the excavated samples available. The current terminology for Romano-British towns, the large major urban towns (*coloniae, municipiae, civitas* capitals) and minor urban or nucleated settlements, continue to be used despite them not being entirely satisfactory in the face of the heterogeneity of settlement characteristics and urbanism (Millett 2001, 64; Mattingly 2006, 356-357). Ideally, the urban character of a Roman site would be determined by considering its size, settlement density, evidence for planning, the public buildings within it and their space and display, residence patterns and house types. Classifying major and minor urban settlements, their population and economic activity is an ongoing research area. Finds, architecture, cemetery data, faunal assemblages and the functional composition of the artefact assemblage are key for identifying the type of town (Reece 1993; Cool 1995; Cool and Baxter 1998; King 1978, 1999; Dobney 2001; Evans 2001; Millett 2001, 64-66; Laurence et al. 2011, 168-169). Despite these issues raised, the traditional view on settlement hierarchy has been adopted for the purposes of this study. This approach also follows the methodology of settlement classification in previous palaeopathological studies of Romano-British populations (see Roberts and Cox 2003; Gowland 2004; Redfern and Roberts 2005; Redfern 2007, 2008; Gowland and Redfern 2010; Lewis 2010, 2011, 2012; Redfern and Gowland 2012; Redfern et al. 2012; Pitts and Griffin 2012; Bonsall 2013b; Redfern et al. 2015).

Settlements described as 'major urban' are characterised by their size, legal and administrative status (Burnham and Wacher 1990, 1). Millett (1990, 69) and Laurence et al. (2011, 168-169) offered a series of features which describe a major Romano-British town including a grid layout for the street system and organised planning throughout, with public buildings, a forum and spiritual focus. Often, the topography was taken into account prior to building or expansion of these towns, such as location near a river. These major urban settlements would also have main roads leading into, and through the town. City walls or defences were not always present (Laurence et al. 2011, 168). The size of a settlement did not necessarily reflect its status or legal functions. *Londinium*, for example, was spatially vast and complex, but of uncertain legal status, although considered as the provincial capital (Millett 1999, 192). Morley (1997, 48) stated that the title given to a Roman town reflects its relationship to Rome itself, rather than its authority over other towns, which puts the relation of Romano-British towns with each other into question. There are three main types of Roman town: *coloniae*, *municipia* and *civitas* capitals which fulfilled a role as administrative centres (Wacher 1974, 17). *Coloniae* were towns founded early in the Roman occupation and are frequently associated with a military presence (Millett 1990, 85; 1999, 191; Pitts and Perring 2006). These towns are often marked by a high population of army veterans (Wacher 1974, 14). The *municipum*, although similar in function and government to a *colonia* describes a town of lesser rank reflecting the extent of Roman citizenship and Roman law within the town. *Municipia* could be promoted to *coloniae* by receiving full Roman rights (Wacher 1974, 14-18). *Civitas* capitals were intended to provide a governing focus within a specified territory, based on 'Celtic' tribal structures and boundaries believed to have existed in Britain prior to the Roman annexation (Millett 1990, 65). *Civitates* served as self-governing units within the Roman provincial administration, and could be inhabited by citizens and non-citizens alike (Wacher 1974, 14, 27). Some of the *civitates* may have arisen from continuous development of Iron Age *oppida*, whereas others were newly founded by the Roman administration (Millett 1990, 75). A caveat for the interpretation of urban cemeteries is Goodman's (2007, 1-2) "urban periphery", an intermediate zone between town and countryside, which is neither urban nor rural. In Rome and the western provinces, these peri-urban *suburbia* were regarded as the seat for the elite immediately outside of the city walls, an area of economic exchange or cultivation of city plots. It is therefore possible that individuals buried in the major urban cemeteries were not urban in the strictest sense as they were inhabitants of the *suburbia* (Goodman 2007, 76-78; Laurence et al. 2011, 288; Pearce 2015).

There are smaller conurbations which may be described as 'minor urban' sites which are more difficult to distinguish from the rural settlements of villages, farmsteads and *villae* (Burnham and Wacher 1990, 1; Millet 2001, 60). These small towns of the province display some aspects of urbanisation and industrialisation, and differ from the purely agricultural focus of the smaller rural settlements (Burnham 1993; 1995; Hingley 1989, 25). Wilson (2011) also attested that these small towns exhibit evidence for planning and possibly a market in order to facilitate local trade. A common denominator for Romano-British towns, whether large or small, is dependence on the hinterland for agricultural surplus to feed the non-producing urban population, and for taxes and rent paid by the peasant population (Fulford 1982; Mattingly 1997, 210; Morley 1997, 42; Jones 2004). However, it was deemed necessary to introduce separate categories for the major and minor urban settlements of the province, as the small or minor urban towns would have offered a distinct living environment to the bigger conurbations and rural dwellings (Greep 1993; Brown 1995; Millett 2001, 65). Todd (1970) also argued that roadside settlements, a distinct subdivision of what might be termed 'small towns', accommodated traders, craftsmen and a market and were therefore more urban in character than those settlements devoted to an entirely agricultural function. Another example is Springhead in Kent, as it comprises of a roadside settlement and a specialised religious centre with a proposed sanctuary complex (Burnham and Wacher 1999, 192; Barnett et al. 2011). Since the term 'small town' has been widely used in the literature to describe both small urban and large rural settlements, the term 'minor urban' site will be used in this study to describe settlements that are urban in character but not officially classed as major urban sites.

There is an ongoing debate regarding the terminology and definitions of rural settlement types (Millett 2005, 61-67). The matter is further complicated by the frequent discontinuity of rural settlements during Roman influence (Taylor 2007, 8-9). In this study rural settlements include *villae*, farmsteads and villages, as these would have provided a different living environment to the major and minor Romano-British towns (Millett 2001, 65; Jones 2004, 349). Although this classification may be labelled as simplistic, it does allow for easier comparison with other contemporary bioarchaeological studies and is sufficiently descriptive for the purposes of this study. *Villae* are high-status countryside residences and agricultural estates, characterised by a Roman building style as the residence of the wealthy provincial elite (de la Bédoyère 1993, 55; King 2004). Hingley (1989, 23) referred to non-*villa* sites as an overarching term for any rural settlement not associated with *villa* buildings which includes any settlement from an isolated farmstead occupied by one family unit to nucleated villages. Farms would have not been too dissimilar to earlier Late Iron Age dwellings primarily concerned with an agricultural function, whereas villages are defined as a group of buildings of similar size and status in a rural setting (King 2004, 350). Grouping *villa* sites with villages and farmsteads is problematic due to the considerable social inequality of the inhabitants across these sites (Faith 1997; Parkins 1997, 83; Taylor 2001b, 49; Millett 2005, 61-67; McCarthy 2013, 8). However, it is generally assumed that the permanent residents at these estates were the workforce. Additionally, in this study only one cemetery of a potential nearby *villa* site at Watersmeet, and one instance of intramural burial on a *villa* complex (Dewlish) are included, where the mode of burial and bioarchaeology of the remains are not suggestive of high status.

The Romano-British economy was largely agricultural, and the countryside would have undergone substantial changes in land-use and ownership to provide for the urban consumer population, especially during the later periods of Roman rule (see Jones 1982; Whittaker and Garnsey 1997; Taylor 2001b, 54; Fulford 2004; Millett 2005, 61-67; Mattingly 2006; Laurence et al. 2011, 288; White 2014, 8, 11). We are restricted in the observation of these changes as cultural artefacts, such as inheritance practices, landownership and social hierarchies cannot be excavated (Roberts 2014, 52). Rural sites clustered in the hinterland of a larger town are problematic, as they may be dependent on the town both economically and socioculturally, more so than those increasingly peripheral or isolated villages (Laurence 2011, 288; White 2014, 8, 11). However, the density of urban settlements in Roman Britain is low compared to other Roman provinces (Laurence 2011, 288). Current models of life in the Romano-British countryside consider *villa* economies, or generally estates managed by landowners, with a peasant population that cultivates the land as tenants or freeholders, living either on the estate or surrounding villages (Taylor 2001b, 56; Millett 2005, 61-67; Mattingly 2006; McCarthy 2013, 7; Breeze 2014). To date, it is estimated that around 50,000 rural sites are known across England alone (Mattingly 2004, 14; Taylor 2007, 9; Fulford and Holbrook 2014, 43; also see forthcoming publications by the 'Rural Settlement of Roman Britain' project at the University of Reading). The overwhelming majority of the Romano-British population would have lived and worked in the countryside. However, unfortunate for bioarchaeological investigations, skeletal remains from rural cemeteries are scarce (Mattingly 2006, 356), and studies comparing urban and rural health are only recently emerging (Pitts and Griffin 2012; Redfern et al. 2015).

4.1.3. The major urban sites

The major urban sample covers eight Romano-British major towns, which are presented here in order of the total number of skeletons recovered (Fig. 4.1). Skeletal data was extracted from site reports of Leicester and Lankhills, Winchester, and the Museum of London Wellcome Osteological Research Database for Roman London, and included in the combined study sample. Additionally, raw data on the non-adult skeletons from Poundbury Camp, Dorchester was directly incorporated. Primary skeletal data was collected by the author for the non-adult skeletal archives of the northern, western and eastern cemeteries of Roman Winchester, Butt Road in Colchester, Bath Gate in Cirencester, the cemeteries at 35 Kingsholm Road, Kingsholm Close and Gambier-Parry Lodge in Gloucester and Trentholme Drive in York.

4.1.3.1. Poundbury Camp, Dorchester, Dorset (3rd-5th century AD)

The cemetery at Poundbury Camp served the *civitas* capital of *Durnovaria*, present-day Dorchester, in Dorset, which was excavated between 1966 and 1982 (Wacher 1974, 316; Molleson 1993; Smith 1993, 1). A total of over 1200 burials were recovered from the cemetery dating from the 1st century BC to the 5th century AD, and are currently held at the Natural History Museum in London. The Romano-British sample comprises of 796 adults and 45.7% (n=364) non-adults (Lewis 2010). Farwell and Molleson's original report (1993) gives a general overview of the cemetery and its three marginal peripheral groups. The main cemetery was arranged in neat rows, with men, women and children of all age groups, possibly indicative of family plots (Fig. 4.2). The main cemetery holds the majority of burials (over 1000) and exhibits two distinct burial groups, which may be indicative of changing belief systems during the late Roman period. One group is characterised by single inhumations aligned east-west without grave goods, and coffins and gypsum or plaster packing. This group also contains 11 mausolea, probably for high status individuals. Individuals in the other group were aligned north-south and interred with a variety of grave goods and hobnailed shoes (Molleson 1989; Farwell and Molleson 1993, 30; Sparey-Green 2004).

Recent work carried out by Lewis (2010, 2011, 2012) has argued that the non-adults from Poundbury are exhibiting a marked prominence of ill-health which needs to be evaluated and compared to other Romano-British non-adult skeletal data. The children from Poundbury Camp are also the first to be identified as exhibiting skeletal evidence for tuberculosis and thalassaemia in Roman Britain. The raw data produced by the palaeopathological analysis undertaken by Lewis was incorporated into the combined study sample (Lewis pers. comm.).

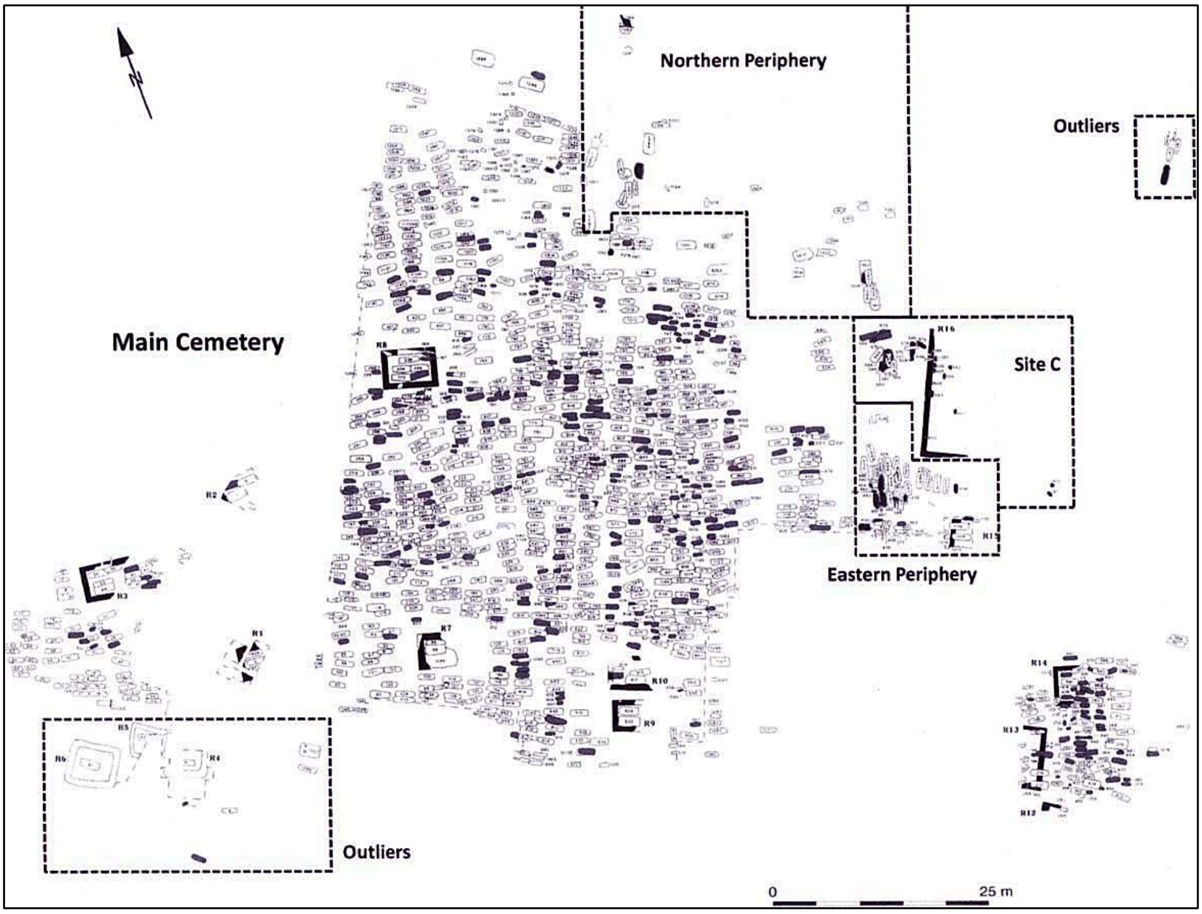


Figure 4.2. Poundbury Camp Romano-British cemetery, non-adult graves are shaded (from Lewis 2010, 407)

4.1.3.2. <u>Butt Road, Colchester, Essex (4th-5th century AD)</u>

The *colonia* of *Vitricensis Camulodunensium* was founded on the *oppidum* of *Camulodunum* and is now contained within modern day Colchester in Essex (Wacher 1974, 104; Brooks 2006; Black 2006). The most outstanding feature of the Roman town would have been the Temple of Claudius which may have emphasised the notion of a cult centre (Crummy 1997, 59; 2006). Additional Romano-Celtic temples have been found, alongside an early 4th century church in the Butt Road cemetery, further strengthening the argument for an important centre of worship at Roman Colchester (Crummy 2006). Wacher (1974, 110) suggested that the architecture of the townhouses displayed a more Mediterranean than Romano-British influence, perhaps indicating that Roman Colchester had a high population of Roman citizens and veterans. Indeed, the early Roman settlement at Colchester was a legionary fortress and a subsequent *colonia* in the making which was destroyed by the Boudiccan revolt in AD60 (Crummy 1993a; Black 2006). Recent archaeological investigations have also attested prehistoric activity at the site, perhaps indicating occupation that pre-dates the early Roman fort (Brooks 2006).

The burial ground at Butt Road has been extensively excavated from 1976-1979, and during 1986 and 1988 by Colchester Archaeological Trust (Crummy and Crossan 1993, 4). The cemetery site is situated just outside of the Roman walled town by the main south-west gate (Fig. 4.3). The phases of the cemetery dating to the 4th and 5th centuries have revealed the remains of 121 non-adults (17.3%) out of a total of 700 recovered individuals (Crummy and Crossan 1993, 62; Pinter-Bellows 1993).

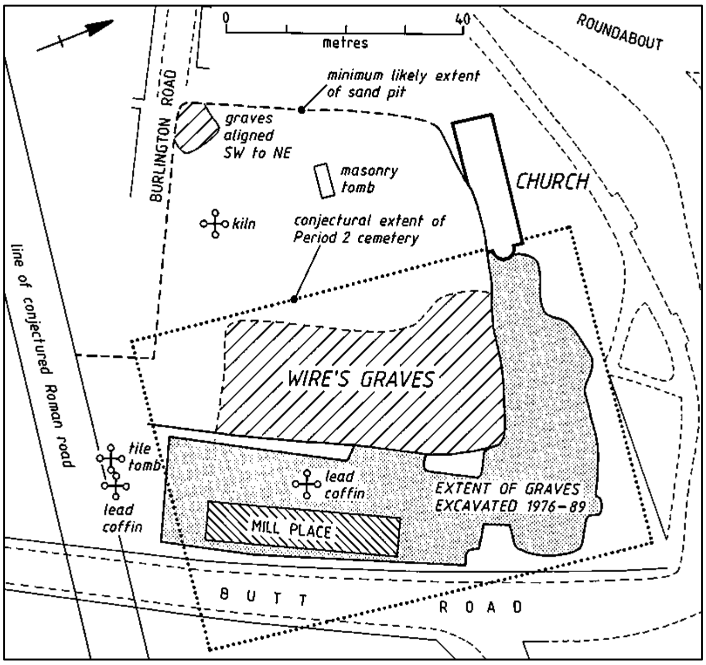


Figure 4.3. Original plan of the extent of the 4th century AD cemetery at Butt Road, Colchester (from Crummy and Crossan 1993, 6)

Most of the individuals were aligned east to west, with some neo- and perinates buried in pairs, and one middle-aged female found buried with a 3-4-year old (Crummy and Crossan 1993, 57, 92, 105). The cemetery also contained multiple burials within timber vaults including non-adults of all age groups, and has been interpreted as possibly early Christian (Crummy and Crossan 1993, 114-115; Watts 1993). Grave goods comprised of glass vessels, armlets, pottery and textiles (Crummy and Crossan 1993, 128). The skeletal archive is currently curated in Colchester Museum, where 109 non-adult individuals were located and recorded.

4.1.3.3. Gloucester, Gloucestershire (2nd-4th century AD)

The *colonia* of *Nervia Glevensium*, modern Gloucester, is set in Gloucestershire, within reach of the river Severn. *Nervia Glevensium* arose from a legionary fortress established during the second half of the 1st century AD, with an initial focus at Kingsholm to the north of the later *colonia* (Wacher 1974, 137; Hurst 1986, 3). There is evidence for continuity between the initial fortress and later *colonia* (Hurst 1986, 142). Gloucester would have accommodated a relatively large population of veterans, whose presence may be reflected in the planning and layout of the town. In terms of architecture and amenities, Gloucester was heavily influenced by Roman ideals, especially after the 2nd century AD (Wacher 1974, 139-150).

Excavations of three burial sites of Roman Gloucester have recovered non-adult inhumations dating to the 2nd-4th centuries AD, including the cemeteries at 76 Kingsholm Road/Kingsholm Close, 35 Kingsholm Road and Gambier-Parry Lodge (Heighway 1980; Hurst 1985; Mullin 2006). Gloucester City Excavation Unit excavated a total of 416 skeletons, but only 8 non-adults (1.9%) in 1972 at Kingsholm Close (Hurst 1985; Roberts 1989) (Fig. 4.4). Gloucester and District Archaeological Research Group undertook a later project at 35 Kingsholm Road in 1982 with 87 burials, eight of which are non-adults (9.2%), and at Gambier-Parry Lodge in 1983 with 55 individuals (21.8%non-adults, n=12) (Finch 2011). No perinates were found at the three sites. The unstratified skull of a child at Gambier-Parry Lodge has been reported to display rhino-maxillary syndrome indicative of leprosy (Lewis 2002b; Finch 2011).

The skeletal archive for Kingsholm Close, 35 Kingsholm Road and Gambier-Parry Lodge is currently held at the Biological Anthropology Research Centre at the University of Bradford, where a total of 29 non-adults have been recorded for Roman Gloucester.

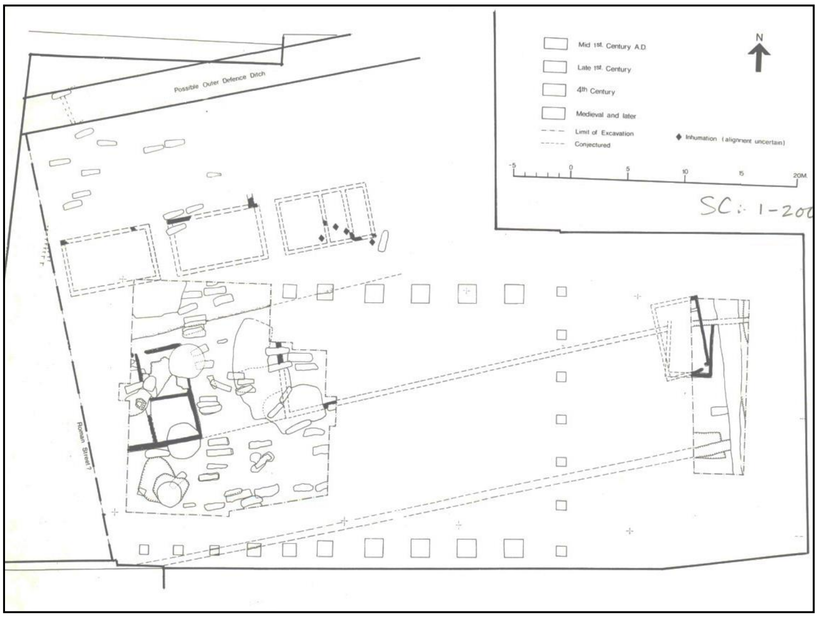


Figure 4.4. Plan of the 1972 excavations of areas 1 and 2 at Kingsholm Close (reproduced with kind permission from Gloucester City Council)

4.1.3.4. Bath Gate, Cirencester, Gloucestershire (4th century AD)

The late Romano-British cemetery at Bath Gate, Cirencester, in Gloucestershire relates to the walled town and *civitas* capital of *Corinium Dobunnorum* (Wacher 1974, 289) (Fig. 4.5). The town grew out of an initial military settlement and during its heyday was significant in its wealth and architectural grandeur (Wacher 1974, 294; Holbrook 1998, 18). The town continuously expanded throughout the Roman period until it became one of the largest conurbations of the province. Industrial activity and trade would have been high, as well as focussed agricultural activity in its hinterland (McWhirr 1986, 78; 1993).

Excavations of the main cemetery site at Bath Gate between 1969 and 1976 by Cotswolds Archaeological Trust yielded a total of 362 individuals, 63 (17.4%) of which are non-adults (Wells 1982, 136) (Fig. 4.5). An additional non-adult of around 13 years was recovered from a separate burial area to the north of the site (Wells 1982, 197). As a general observation, most individuals were interred in a supine position, with both south-north and west-east alignment. Three children were recorded in a prone position and a further three in a supine position lying on their side (Viner and Leech 1982, 76-81). The site report does not yield sufficient detail on the non-adult palaeopathology, and the skeletons were therefore re-assessed by the author. A total of 64 individuals were located and recorded at Corinium Museum.

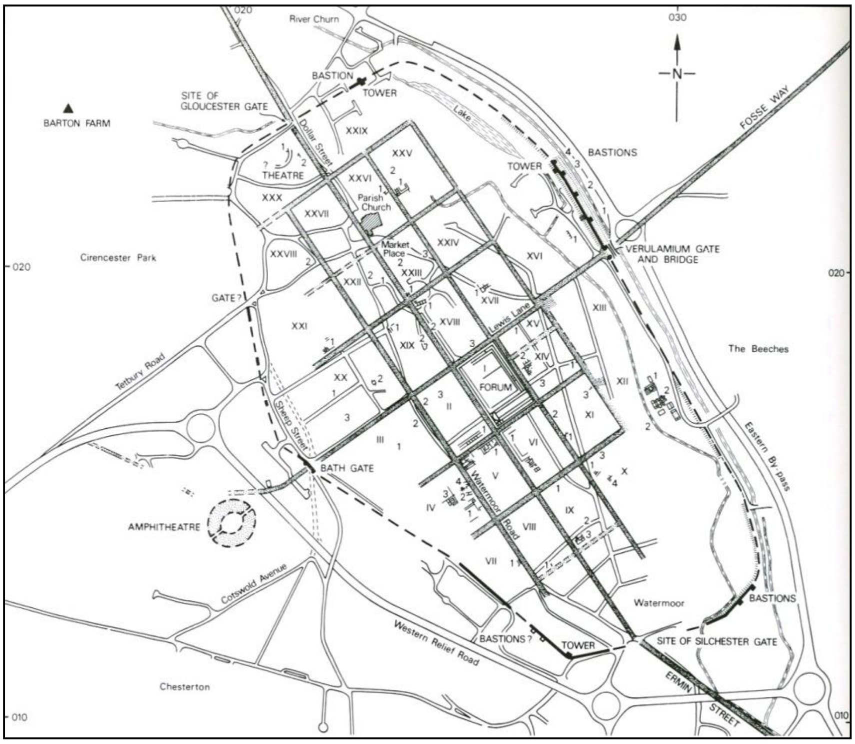


Figure 4.5. Plan of Corinium Dobunnorum (from McWhirr et al. 1982, 20)

4.1.3.5. Trentholme Drive, York, North Yorkshire (3rd-4th century AD)

The late Roman cemetery at Trentholme Drive relates to the *colonia* of *Eburacum*, modern-day York in North Yorkshire. York is slightly different in character to most other *coloniae* regarding its development. York did not arise from a pre-Roman settlement which turned into a *colonia*, but most likely arose from a settlement relating to the Romano-British legionary fortress on the river Ouse. York subsequently underwent wide-ranging reorganisation and planning during the 3rd century AD (Wacher 1974, 156; Ottaway 1993, 11). York was an important town in the province, especially considering its location at the northern fringes of the Empire and close proximity to Hadrian's Wall (Ottaway 1993). York frequently received attention and visits from high-ranking Roman officials, including the emperor. The emperor Constantius died in York in AD 306, and his son and successor Constantine was subsequently proclaimed emperor of Rome in York. Headquarters of the governor and the provincial administration were in York, important functions that increased especially since the emperor Constantine visited (Bidwell 2006). The population would have been diverse, comprising of veterans from the nearby fortress, as well as merchants and traders, contributing to its affluence and wealth in industry and trade, and accounting for the architectural evidence of overseas influences (Wacher 1974, 165-166, 168).

The excavations at Trentholme Drive cemetery were undertaken between 1951 and 1959 by Peter Wenham and volunteers of the York Excavation Committee (Ottaway 2009). The burials were subsequently discussed in Wenham (1968). The burial catalogue holds a record of 343 inhumations with 63 non-adults (18.4%). A scan of the burial records in the site report revealed one perinate within the total non-adult sample of 63 individuals with the younger age groups less well represented (Wenham 1968, 129-144). Of note are the remains of a 12-year old, buried in a flexed position under a cairn. The burials are aligned north-south or east-west with no discernible pattern and the use of coffins was widespread (Wenham 1968, 33, 39) (Fig. 4.6). Regarding the body position of the inhumations, all children and most adolescents were flexed lying on their sides (Wenham 1968, 38). The skeletal archive for the Trentholme Drive assemblage is currently held at the Natural History Museum, London, and the Yorkshire Museum in York. The remains of 24 non-adults were located and recorded at the Natural History Museum. Yorkshire Museum only holds disassembled adult individuals, and this archive was therefore not accessed (McIntyre pers. comm.).

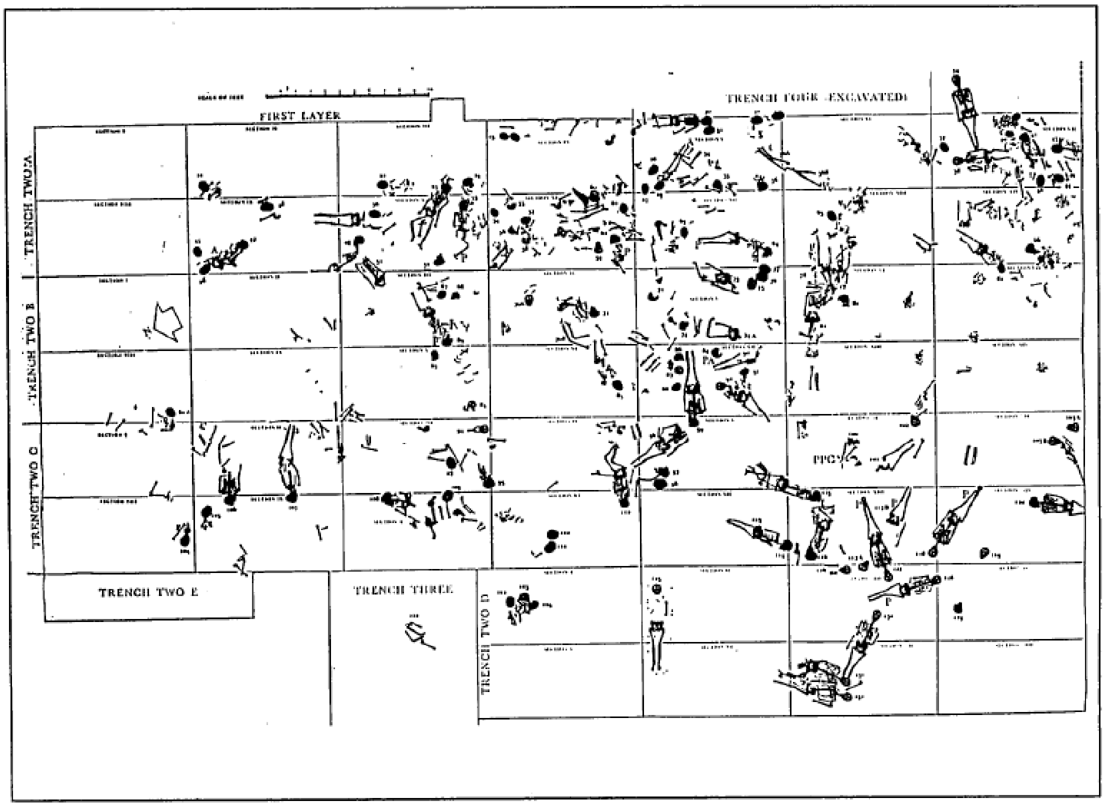


Figure 4.6. Layer 1 of the cemetery at Trentholme Drive (from Wenham 1968, 35)

4.1.3.6. Roman Winchester, Hampshire (1st-4th century AD)

The walled Roman town of Winchester, *Venta Belgarum*, in Hampshire has a long occupation history and was connected to other major Romano-British conurbations like Cirencester via its extensive road networks (Wacher 1974, 286; Scobie et al. 2008, 7). The final stages of development of the town would have been complete by the 2nd century AD (Qualmann 1993). One of the most recent site reports on excavations at Roman Winchester by Booth et al. (2010) suggests a dynamic population and the possibility that *Venta Belgarum* was the site of an Imperial weaving shop. This would have influenced its character as a trading and manufacturing centre on not just a local but also national scale and marked its population as one including official and military communities. Several cemetery sites have been excavated for Roman Winchester, and are described below.

4.1.3.6.1. The Northern, Western and Eastern Cemeteries (1st – 4th century AD)

The three main cemetery zones of Roman Winchester comprise of sixteen sites, which have been excavated in the years 1971-1986 (Fig. 4.7). The excavations have been undertaken as a combined effort of Winchester City Council, Hampshire County Council and the Ancient Monuments Inspectorate from the Department of the Environment (Ottaway et al. 2012, 4). A total of 414 individuals have been recovered from the northern, western and eastern cemetery zones, with an additional 11 cremation burials (Browne 2012, 210). Non-adults make up 38% of the sample with 156 individuals. The distribution of non-adults varies across the cemetery zones, with 35% in the Northern cemetery, 61% in the Western cemetery and 34% in the Eastern cemetery (Browne 2012, 217). The age distribution varies greatly between the zones. Non-adults from 0-17 years are represented in the Northern and Eastern cemetery, however the late Roman non-adult inhumations of the Western cemetery are mainly infants and neonates (Browne 2012, 212-217). Only few pathologies have been reported in the children, and dental pathology is almost entirely absent (Browne 2012, 222). Browne (2012, 225) described an infant with inflammation of the external auditory meatus, an infant with periostitis of the long bones and a 3-5-year old with porotic hyperostosis, cribra orbitalia and endocranial lesions.

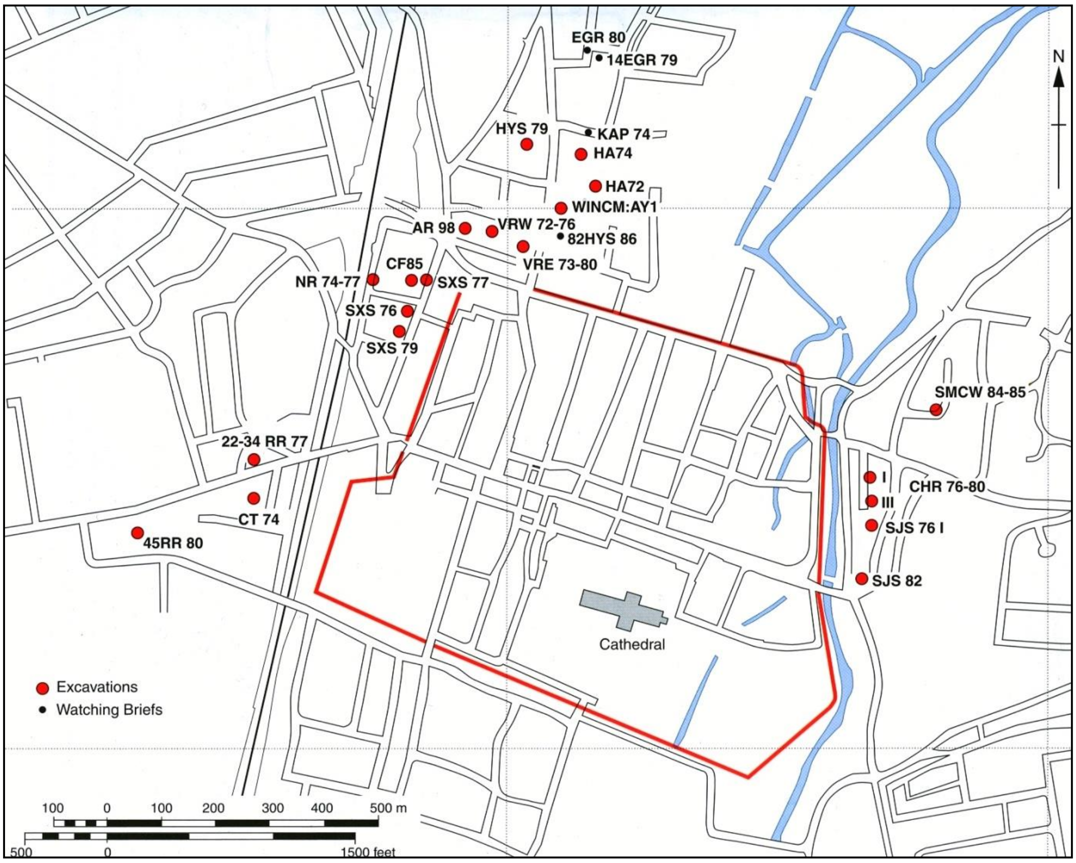


Figure 4.7. Excavations of the cemeteries of Roman Winchester. Codes: AR=Andover Road, CF=Carfax, CHR=Chester Road, HYS=Hyde Street, NR=New Road, SMCW=St Martin's Close, VRE=Victoria Road East, VRW=Victoria Road West (from Ottaway et al. 2012, 9)

The palaeopathology data of the non-adults from Lankhills was already included in the combined study sample, as the site report by Booth et al. (2010) features a detailed account of individual burials and their respective osteological data. It was decided to re-assess the skeletal pathology of the non-adults from the remainder of the Roman cemeteries in and around Winchester to obtain more detailed palaeopathological and age-at-death information. The sample recorded is a selection of the sites with the highest number of non-adult individuals, and listed below (Table 4.3). The skeletal archive is currently curated at Winchester Museums, where 165 non-adult skeletons were located and recorded.

Table 4.3. Sites and numbers of individuals in the Northern, Western and Eastern cemeteries of Roman Winchester

Suburb	Site name	Date (century AD)	Excavation date	N individuals	n non-adults reported (%)
Northern	Victoria Road West	Late 1st-late 4th	1972-1980	121	53 (43.8)
	Victoria Road East	Late 1st-late 4th	1973-1979	100	83 (83.0)
	Andover Road	4th	1998	33	8 (24.2)
	Hyde Street '79	4th-early 5th	1979	29	5 (17.2)
Western	Carfax	3rd-4th	1985-1986	65	27 (41.5)
	New Road	Late 3rd-4th	1974-1975	23	19 (82.6)
Eastern	Chester Road	Late 3rd-early 5th	1976-1980	94	23 (24.5)
	Saint Martin's Close	4th-5th	1985	34	6 (17.6)
Total N				499	**224 (44.9)**

(from Browne 2012, 212-217); % of total site sample

4.1.3.6.2. Lankhills (4th century AD)

The burial ground at Lankhills is set just outside the city's north gate and dates to the 4th century AD (Wacher 1974, 286). Although it is accepted that the use of the cemetery commenced during the early 4th century AD, its use remains uncertain after AD 400 as radiocarbon dating has produced conflicting results (Booth et al. 2010). The Lankhills cemetery has been excavated on two separate occasions, initially by Clarke between 1967 and 1972, and more recently by Oxford Archaeology (OA) from 2000 to 2005 (Clark 1979; Booth et al. 2010). Only the age and sex data from the first 451 inhumations recovered by Clarke has been published (Harman 1979, 342), which is based on summaries rather than individual records and therefore unsuitable for inclusion in the current study. Re-analysis of this collection was also not possible at the time of study. The skeletal archive of these early excavations is held at Winchester Museum, where the skeletons from the more recent OA excavations will also be deposited in the near future.

The detailed report by Booth et al. (2010) discussed the burial archaeology and palaeopathology of 313 graves of the northern area of the cemetery located to the north of *Venta Belgarum* (Booth et al. 2010, 17). A total of 284 inhumation burials yielded 69 non-adults (21.4%) (Booth et al. 2010, 33). The burials were spread across the cemetery sites, mostly all roughly aligned along the west-east axis (Booth et al. 2010, 54-55) (Fig. 4.8).

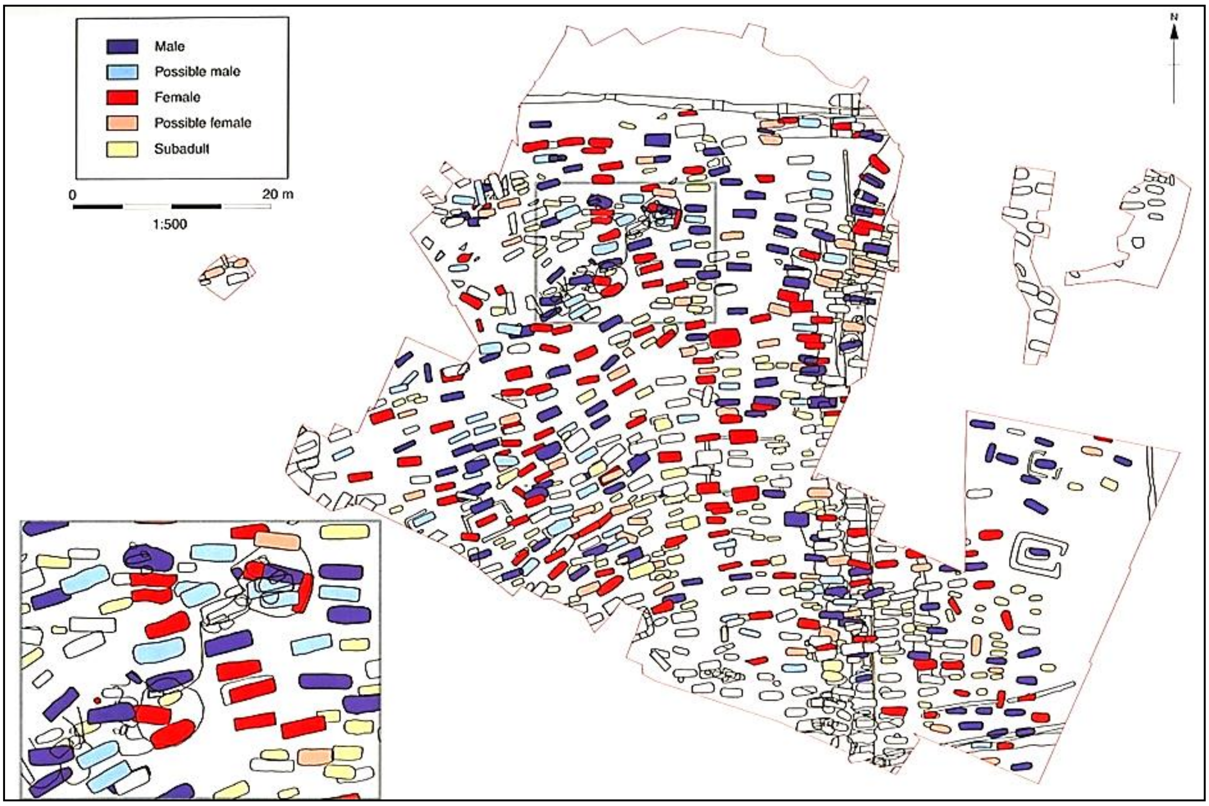


Figure 4.8. Romano-British cemetery at Lankhills, Winchester (from Booth et al. 2010, 467)

Infants have been recovered from unusual and multiple burials: one infant was recovered from a ditch, two neonates on separate occasions were placed in a grave with an adult female, and one infant was reported as decapitated (Booth et al. 2010, 33, 37). Most of the non-adults (70.0%) were interred within a coffin (Booth et al. 2010, 481). In contrast, only one of the six neonates within the sample was found in a coffin, indicating that more formal burial rites were only bestowed on older children (Booth et al. 2010, 482). Evidence for hobnailed shoes or grave goods was found in about half of the non-adult inhumations. Non-adults were buried in a supine position, with only few exceptions. Five non-adults below the age of three were recovered flexed on the left side, one adolescent on the right side and one child aged 4-7 years was buried prone (Booth et al. 2010, 40-41). Palaeopathological analysis of the whole assemblage has recently been undertaken and published by Clough and Boyle (2010), producing comprehensive and detailed data which was incorporated into the combined study sample.

4.1.3.7. Roman London

Roman London, *Londinium Augusta*, was the provincial capital of *Britannia*, serving as the administrative and financial centre of the province (Wacher 1974, 84-88; Perring 1991, 109; Wallace 2013). *Londinium* was probably the most 'Roman' of cities in the province (Perring 1991). Wacher (1974, 97) described Roman London as rather unusual compared to the larger Romano-British settlements, as the city lacked consistent fortifications and was built either side of the river Walbrook which ran through its centre (Fig. 4.9).

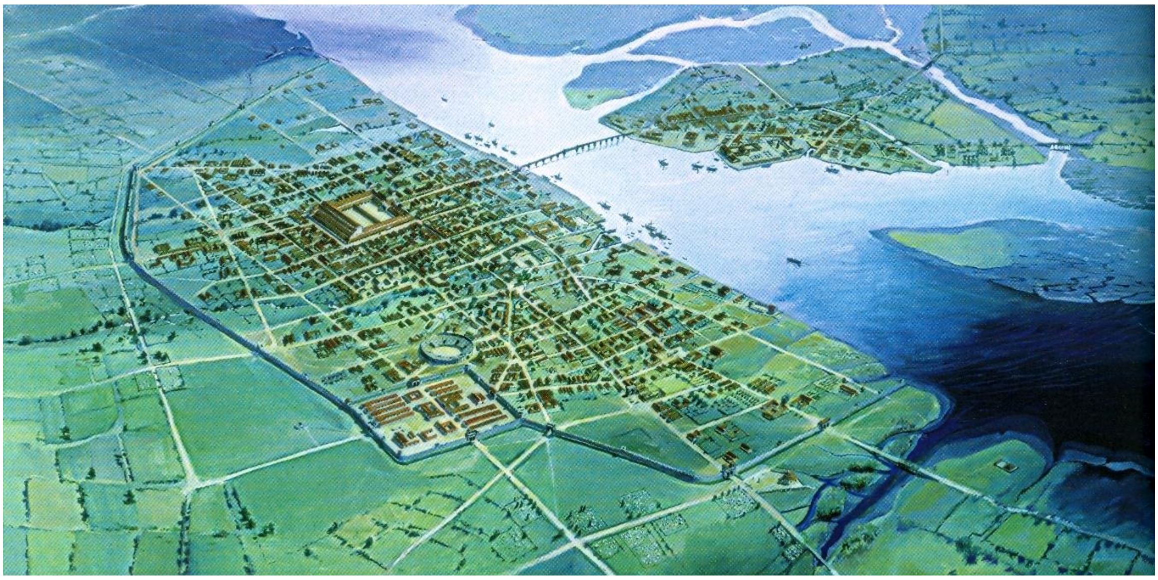


Figure 4.9. Reconstruction view of late Roman London, showing the defences, amphitheatre and forum (from Rowsome 2008, 32)

The hypocausts, bath houses and wide range of material culture found in excavations of Roman London attest to a dynamic population of varying economic and social status in a highly urbanised environment. Later Roman London during the 3rd and 4th centuries AD may have been subject to military and administrative changes, which may have impacted on the public and administrative life of its inhabitants (Perring 1991, 114). *Londinium* would have been the largest urban conglomeration in Roman Britain, with possibly around 30,000 inhabitants (Barber and Bowsher 2000).

Excavations in London have revealed several cemetery sites outside of the Roman city (Fig. 4.10). The non-adults from Roman London included in the combined study sample stem from two Romano-British cemetery contexts, summarised as the western and southern cemeteries. The Western cemetery, lying north of the River Thames, concentrates along the Roman roads leaving the city to the west, around the modern day area of Newgate Street and Aldersgate Street. The Southern cemetery to the south of the River Thames runs along the junction of two Roman roads, relating to Stane Street and Watling Street (Barber and Bowsher 2000). Skeletal data is available from the Wellcome Osteological Research Database (WORD) maintained by the Museum of London, where all the remains are currently archived. The non-adult palaeopathology data was extracted from the WORD database. The skeletal materials had been analysed and recorded in sufficient detail to warrant incorporation into the current work without the need for repeated analysis.

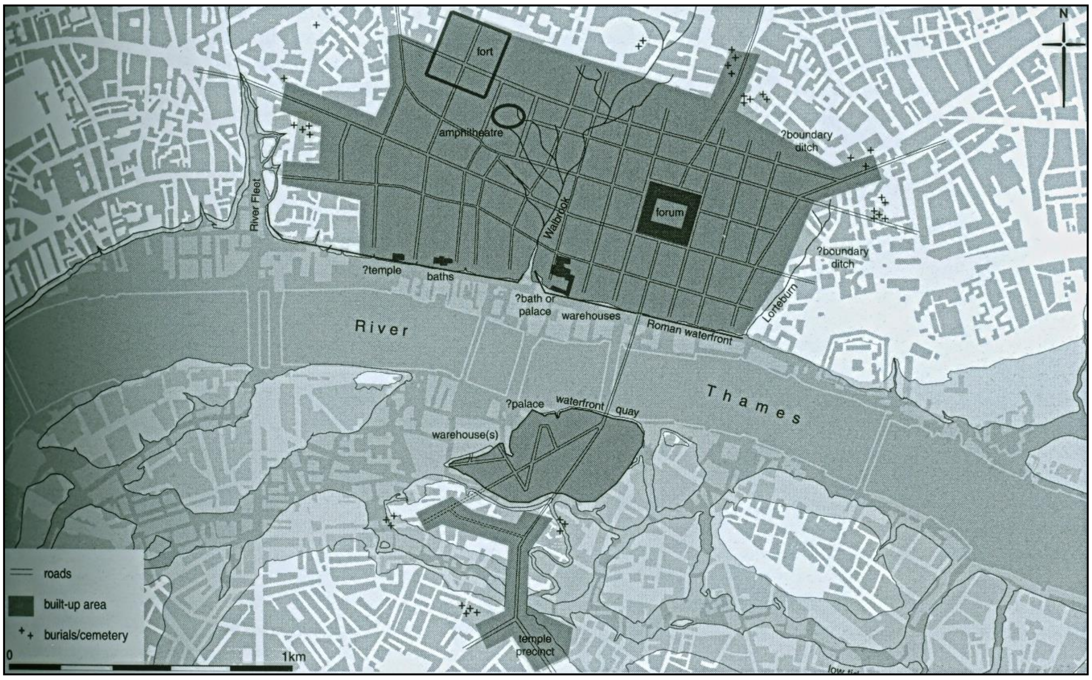


Figure 4.10. Roman London during the 2nd century AD, marking the cemetery outside the town defences (from Rowsome 2008, 29)

Although the skeletal archive from the Eastern cemetery has been published in Barber and Bowsher (2000), the burial catalogue does not provide information on individual skeletal pathology. A total of 550 burials are discussed in Conheeney’s (2000) skeletal report, and 129 (23.5%) of these have been aged to 18 years and younger, however the palaeopathology is presented in summary tables only. Unfortunately, access to the skeletal archive for re-analysis was not possible at the time of study. All Romano-British skeletal collections held at the

Museum of London are currently closed for external researchers and the only samples available for Roman London are those that can be accessed via WORD.

4.1.3.7.1. London West (4th century AD)

The excavations relating to the Western cemetery in London yielded a total of 133 skeletons from three separate excavations, providing a sample of 32 non-adults (24.1%). The oldest excavation dates to 1979 at St Bartholomew's Hospital Medical School at Giltspur Street. This site yielded six non-adult skeletons out of a total of 16 recorded individuals. Some of the burials were organised into clusters, the latter possibly indicating family plots. Individuals were mostly interred in coffins, some also exhibiting grave goods (Bentley and Pritchard 1982). Another excavation at Giltspur Street, West Smithfield and Cock Lane in 1989 comprised of 23 non-adults (23.5%) in a total sample of 98 skeletons. This site covers a rather long period from the Late Bronze Age through to the post-medieval period. Both excavations were undertaken by the Department of Urban Archaeology and are published in Schofield and Maloney (1998). The most recent excavation was at the multi-period site of Atlantic House, Holburn Viaduct by Museum of London Archaeology Service with three non-adults (15.8%) out of a total of 19 individuals, and published by Watson (2003). The burials were arranged loosely into clusters with two groups of intercutting graves, as well as evidence for coffins and some finds of pottery. Graves were generally aligned north-south or east-west (Watson 2003). It is of note that the excavations relating to the Western cemetery have not produced any perinatal individuals. The sites referred to here as the sample from Roman London West are solely those with non-adult skeletons that were accessible via the WORD database and could be included in the combined study sample.

4.1.3.7.2. London South (4th century AD)

For the sample from the Southern cemetery of Roman London, five sites have been included from the WORD database, with 18 non-adult skeletons (45.0%) in a total of 40 individuals. The oldest excavation was undertaken in 1982 at Guy's Hospital Redevelopment (Area 7), St Thomas Street, by Southwark and Lambeth Archaeological Excavation Committee, spanning use from the Roman to the post-medieval period. Only one non-adult was found in a total of three recovered individuals. Another excavation dating to 1984 at Courage Brewery, Park Street, a multi-period site spanning the Roman through to the post-medieval period, was undertaken by the Department of Greater London Archaeology. Six skeletons were recovered, half of which were non-adults. Museum of London Archaeology Service excavations in 1992 and 1994 at Redcross Way and Grouting Shaft, Redcross Way, yielded two and one Romano-British non-adult inhumations (total of five and two individuals respectively). The latest excavation included in the archive was undertaken at 165 Great Dover Street in 1996 by the Museum of London Archaeology Service and published in Mackinder (2000). WORD provided osteological data for 11 non-adults (45.8%) in a total of 24 recorded individuals. The excavations revealed a roadside walled cemetery structure with the majority of individuals buried prone and in a wooden coffin. The relatively high number of non-adult skeletons in the sample is indicative of family plots in the burial ground (White 2000, 26).

Similar to the Western cemetery, only sites that have included non-adult skeletons are incorporated in the current research, although a number of additional sites have been excavated as part of the Southern cemetery.

4.1.3.8. Clarence Street, Leicester, Leicestershire (3rd-4th century AD)

Ratae Corieltavorum, the Romano-British settlement at Leicester developed into a *civitas* capital based on the site of an Iron Age *oppidum* (Burnham and Wacher 1990, 335). As the town developed, so did its hinterland, the prosperity being reflected in the archaeology of the private dwellings in the town from the 2nd century AD onwards (Burnham and Wacher 1990, 348; Finn 2004, 62). There is evidence for commercial and industrial activity, and the town also provided a religious centre (Burnham and Wacher 1990, 353-354; Connor and Buckley 1999, 57-58; Finn 2004, 62). The centre of the town, alongside the forum, basilica and market was devastated by a fire during the late 4th century AD, which may have initiated a decline in activity at the site (Burnham and Wacher 1990, 357; Connor and Buckley 1999, 59-60).

Excavations in 2001 by Wells Associates and the Archaeology Section, Leicester Museums Service, revealed a managed cemetery in use from the mid-3rd to the mid-4th century AD (Gardner 2005) (Fig. 4.11).

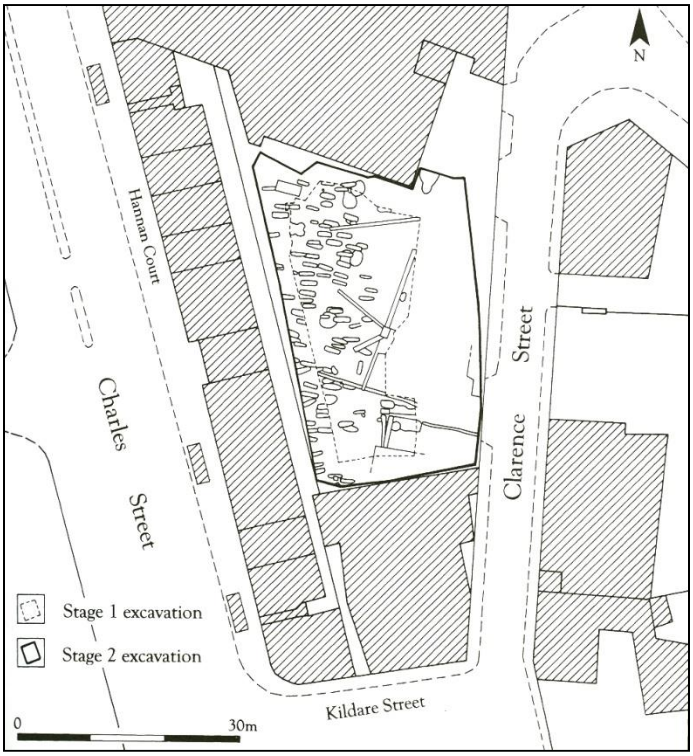


Figure 4.11. Location and excavation plan of the cemetery site at Clarence Street (from Gardner 2005, 29)

The archive is held with the Leicestershire Museums Arts and Records Service. A total of 92 skeletons were recovered, with 12 non-adults (13.0%), most of which are perinates (Waldron 2005, 63). Non-adults were distributed across the cemetery area, and the burial rite was consistent, with supine inhumations, east-west alignment, a general dearth of grave goods and most inhumations with evidence for timber nailed coffins (Gardner 2005) (Fig. 4.12). Generally, pathological conditions are limited to the adult population, apart from one infant with skeletal changes indicative of 'wasting' (Waldron 2005, 67). A single bone of a foetus of 32-36 weeks was found in the grave of a young adult female, which may indicate death during labour (Waldron 2005, 67-68). Overall, the extremely poor preservation of the skeletal assemblage somewhat compromised anthropological analysis (Waldron 2005, 68). Palaeopathological information for 13 non-adult individuals was extracted from the skeletal report and included in the combined study sample.

Figure 4.12. Cemetery map and phasing at Clarence Street, Leicester (from Gardner 2005, 31)

4.1.4. The minor urban sites

Skeletal data from eight Romano-British small towns has been incorporated. The non-adult osteological data from skeletal reports for Springhead and Chesterton was extracted and included in the combined study sample. Primary palaeopathological data was recorded by the author from the non-adults buried at Ashton, Baldock, Ancaster, Great Casterton, Queensford Farm/Mill and Dunstable (Fig. 4.1). The sites are presented in order of the total number of skeletons recovered from their respective cemeteries.

4.1.4.1. Ancaster, Lincolnshire (3rd-4th century AD)

Romano-British Ancaster is situated in Lincolnshire and described as a minor defended settlement. In the area around Ancaster prehistoric settlements and trackways were evident, ultimately leading to a Romano-British settlement and two close-by military sites (Burnham and Wacher 1990, 235). The town expanded mostly during the 2nd century AD and boasted a variety of economic features, such as evidence for pottery and iron-working, as well as a religious focus (Burnham and Wacher 1990, 237, 239).

The cemetery at Ancaster was in use during the 3rd and 4th centuries AD (Fig. 4.13). The site was excavated between 1964 and 1973 and the skeletons are currently archived by English Heritage at Fort Cumberland, Portsmouth. The assemblage has been initially recorded by Cox (1989) in an unpublished report. A total of 327 skeletons are included in the archive, 84 (25.7%) of which are non-adults. It was noted that non-adults were mainly buried in groups across the cemetery and infants made up nearly 30% of the non-adult assemblage.

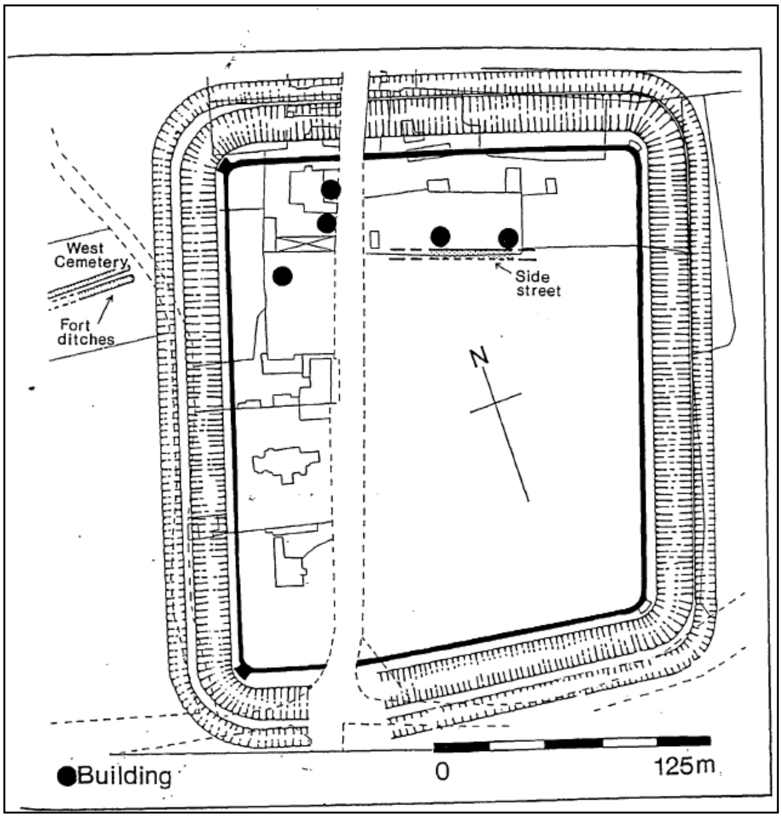


Figure 4.13. Location of the cemetery at Ancaster (from Todd 1975, 216)

Additionally, two perinates were recovered from within the settlement context, associated with building structures. Mortality peaked around birth and at 3-4 years, possibly associated with weaning as hypothesised by Cox (1989). A number of multiple burials were encountered. Two adult females and one adult male were buried with a non-adult and one adult female was interred with a neonate. There were an additional three instances of non-adults buried together, including neonates (Cox 1989). Cribra orbitalia and porotic hyperostosis were mainly found in non-adults. Evidence for tuberculosis was identified in two adult individuals (Cox 1989), and it may therefore be expected in the non-adults upon re-examination. A total of 78 non-adults were located and recorded at Fort Cumberland.

4.1.4.2. Ashton, Northamptonshire (4th century AD)

Roman activity at Ashton was most likely based on an established Iron Age site. The Romano-British undefended settlement is somewhat agricultural in character and may be classed as a small town. The initial Roman roadside settlement underwent restructuring during the 2nd century AD with added road networks and the expansion of the iron-working industry. A lead tank, bearing a Christian monogram may also point towards the settlement displaying a religious focal point (Burnham and Wacher 1990, 279, 281).

The Romano-British cemetery at Ashton dates to the 4th century AD and has been excavated between 1983 and 1984 by Northamptonshire County Council and the Department of the Environment (Frere et al. 1985, 1986). The cemetery area uncovered contained 100 non-adult individuals (33.7%) in a total of 297 inhumations, mainly aligned along the east-west axis (Fig. 4.14). This site remains unpublished to date, with the skeletal archive currently held at Peterborough Museum, where 60 non-adults were located and recorded.

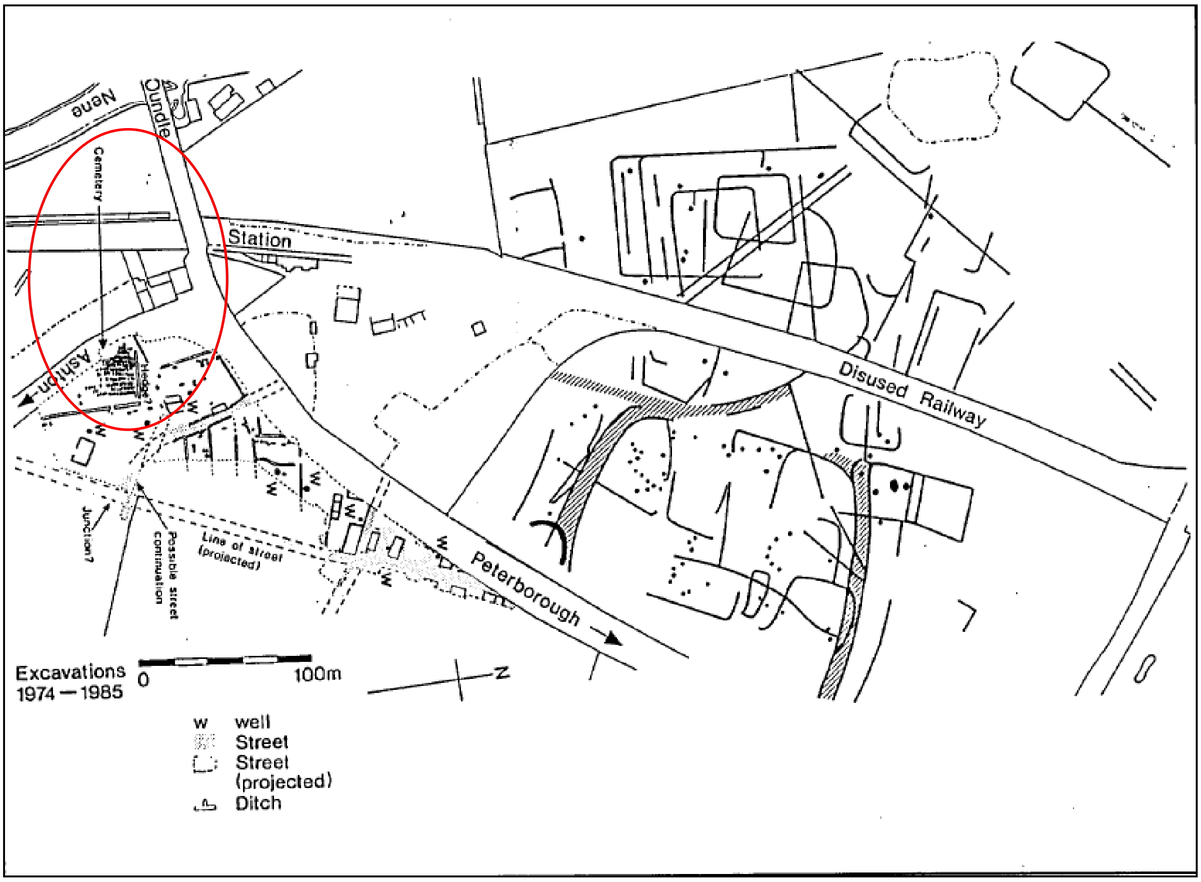


Figure 4.14. Burial locations at Ashton during the 1983 excavations (inhumations are marked by black dots) (from Dix 1983, 19)

4.1.4.3. Baldock, Hertfordshire (2nd-4th century AD)

The Romano-British site at Baldock in Hertfordshire has been discussed by Burnham and Wacher (1990, 281-282) as an undefended settlement with occupation evident from as early as the Iron Age. The site is located on a fertile patch of land, along the intersection of several Roman roads. The site has been classified as a small town, probably predominantly agricultural in character, although with evidence for small scale manufacturing (Burnham and Wacher 1990, 285; Burleigh 1993) (Fig. 4.15).

Burleigh and Fitzpatrick-Matthews (2010) mentioned a minimum of 176 inhumation burials from excavations conducted during the late 1970s, 1980s and early 1990s at Baldock, Area 15 by North Hertfordshire Archaeological Society (Fig. 4.16). In their report on excavations from 1968-72, Stead and Rigby (1986, 393) pointed out a total of 22 infant burials from the same site, 12 of which were found outside of the formal burial ground. The Area 15 cemetery complex is characterised by a mixed burial rite, as inhumation and cremation were performed simultaneously and within the same space (Fig. 4.16). Most of the inhumation burials were however found in the cemetery sites at Royston Road and California (Burleigh and Fitzpatrick-Matthews 2010, 19). The settlement is surrounded by at least nine cemeteries, seven of which follow the inhumation rite (Burleigh 1993).

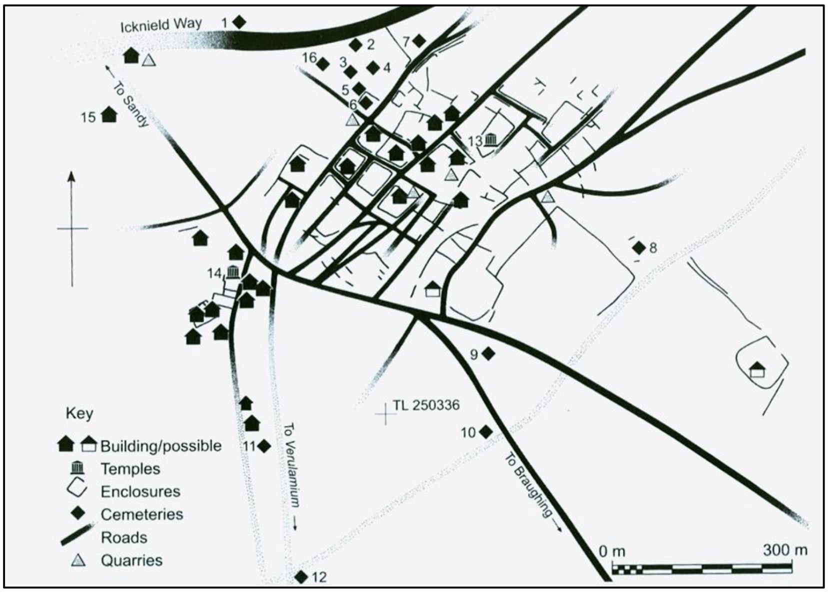


Figure 4.15. Locations of the cemeteries at Romano-British Baldock (from Burleigh and Fitzpatrick-Matthews 2010, 26)

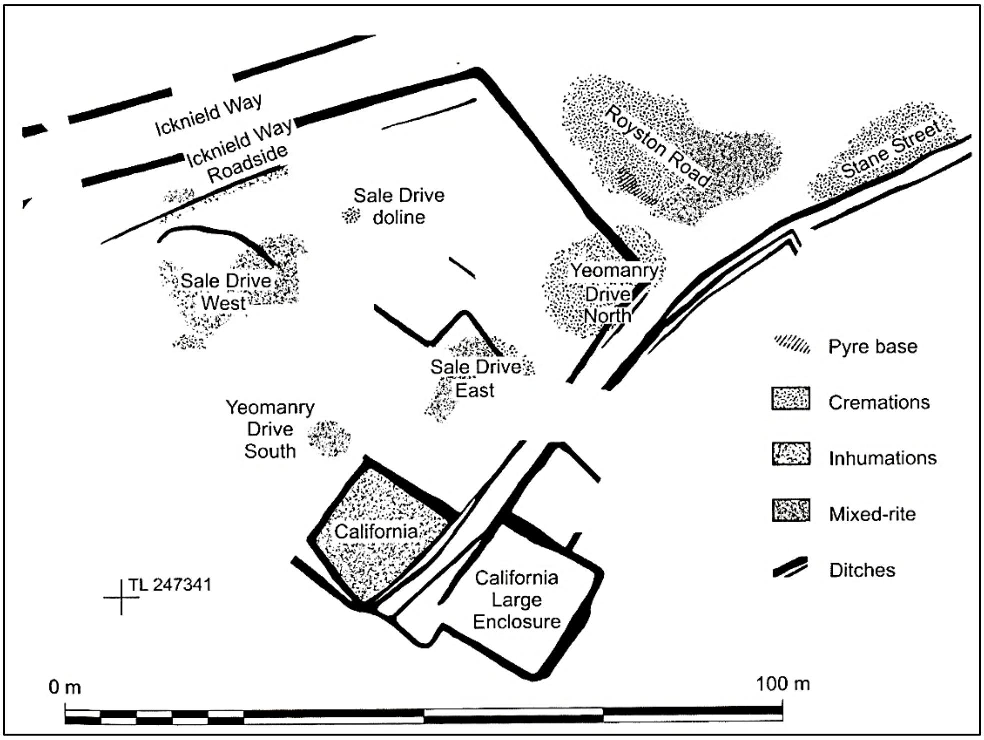


Figure 4.16. The BAL-1 and BAL-15 cemetery sites of Roman Baldock (from Burleigh and Fitzpatrick-Matthews 2010, 19)

The Baldock skeletal archives are held at Hitchin Museum Resource Centre of the North Hertfordshire District Council Museums Service, with a small number of skeletons also stored at the Biological Anthropology Research Centre (BARC) at the University of Bradford. The research visit to the museums store at Hitchin revealed a substantially greater number of skeletons due to continued excavations at the site, some of which remain unpublished. It was not possible to locate the infant burials discussed in Stead and Rigby (1986). An additional 10 non-adults were recorded from a 1994 excavation at Area 15, undertaken by the Heritage Network (Burleigh and Fitzpatrick-Matthews 2010, 19). The skeletal archive is yet to be studied by an osteologist, and it remains to be established how many individuals were recovered in total. The skeletal archive of 1989 excavations at Area 15 yielded a further 57 non-adults, including the ‘triplet burial’. A visit to the Baldock archives at BARC added another 15 non-adults from Area 15. Therefore an overall total of 82 non-adult skeletons were recorded from Roman Baldock.

4.1.4.4. Queenford Farm and Queensford Mill, Dorchester-on-Thames, Oxfordshire (3rd-4th century AD)

The minor walled town of Roman Dorchester-on-Thames was situated in Oxfordshire where the river Thame meets the river Thames (Fig. 4.17). The town would have been on a main Roman road connecting Silchester, Alchester and Towcester, and there are indications for the site having been occupied since the Iron Age (Burnham and Wacher 1990, 117; Morrison 2009, 16, 46). It is likely that the town would have accommodated light industry and, based on its location, benefitted from river communications and trade (Burnham and Wacher 1990, 119-120). There is evidence for continuity of the site into the 5th century AD (Burnham and Wacher 1990, 121; Morrison 2009, 47).

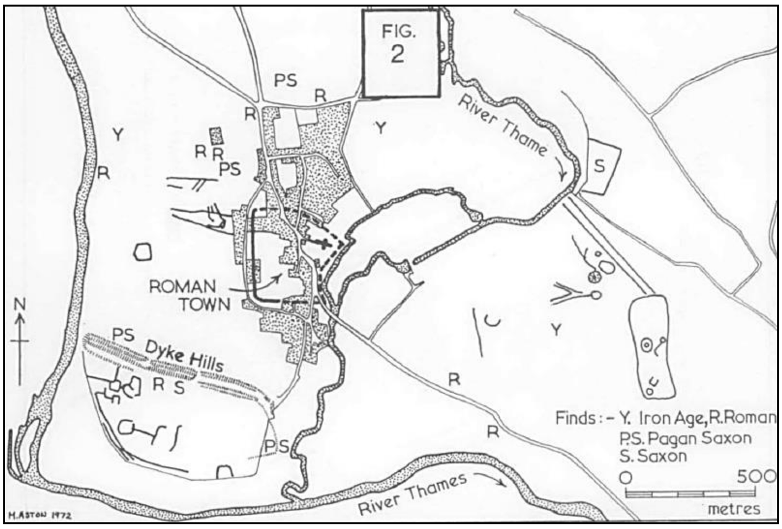


Figure 4.17. The small Roman town at Queensford Farm/Mill, Dorchester (from Durham and Rowley 1972, 33)

The late Roman cemetery at Queenford Farm was excavated in 1972 along its south-eastern corner and in 1981 along its south-western part. The earlier excavation was referred to as Queensford Mill but has later been incorporated into the Queenford Farm skeletal archive, both dating to the late Roman period (Durham and Rowley 1972; Chambers 1987) (Fig. 4.18). In keeping with Romano-British cemetery layouts, the burial ground is situated along a Roman road leading into or away from the nearby Roman town (Chambers 1987). The skeletal archive is held by Oxfordshire Museum Service in Standlake and Oxford Brookes University.

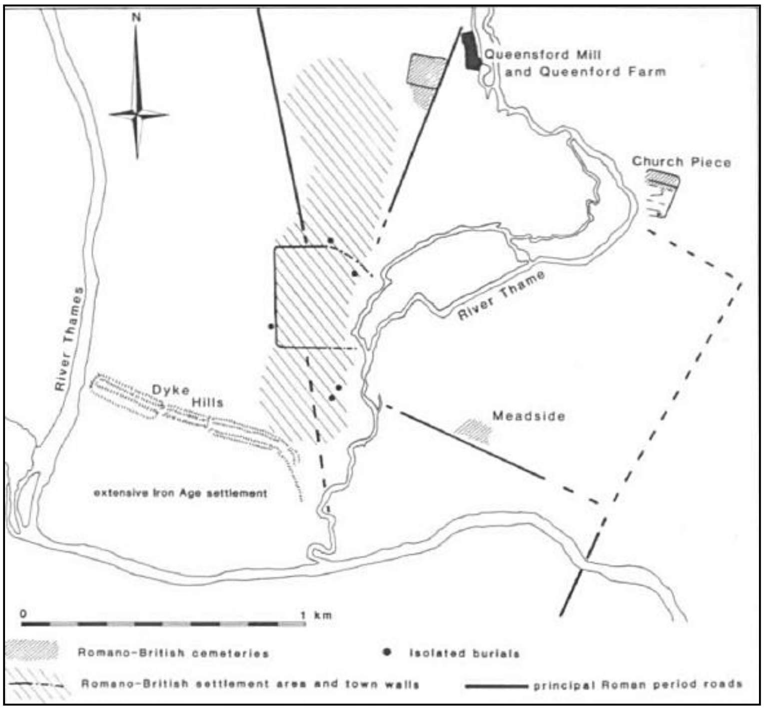


Figure 4.18. The cemeteries of the small Roman town at Dorchester-on-Thames (from Chambers 1987, 37)

The 1972 excavation at Queensford Mill by Upper Thames Archaeological Committee identified close to 200 graves, 78 of which were excavated. The majority of the graves conformed to the east-west alignment and were laid out in rows orientated north to south. Associated finds were identified in a third of the inhumations and are limited to coffin nails or fittings (Durham and Rowley 1972). The skeletal remains recovered from this project are included in the later site report on the Romano-British cemetery at Queenford Farm by Chambers (1987). The later excavation by Oxford Archaeological Unit in 1981 at Queenford Farm saw the identification of a further 102 graves, with 82 inhumations excavated. The graves stem from both within the cemetery enclosure (n=49) and to the south of the enclosure (n=33). All except two inhumations, one of which was aged to 11-13 years, were buried along the west-east axis with heads to the west. Most individuals were interred supine and extended. There was one child buried on its right side with flexed legs. Goods in the form of pottery were associated with three graves and about one third of burials contained evidence for a coffin.

A total of 160 skeletons are discernible from both site reports, with 58 individuals aged to 15 years and below (36.3%). Eighteen non-adults were recovered during the 1972 excavations and 40 stem from the 1981 project (Harman 1987, 60). In the 1987 report, non-adult skeletal pathology focusses on abnormality in shape on the long bones such as bowing, and cranial pathologies, such as premature fusion, also cleft vertebrae and 'osteoporosis' (Harman et al. 1987, 62-63). These finds might suggest developmental defects within this population, as well as metabolic and infectious diseases. A total of 60 non-adult individuals have been located and recorded at Oxfordshire Museum Service and Oxford Brookes University.

4.1.4.5. Great Casterton, Rutland (3rd-4th century AD)

The Romano-British settlement at Great Casterton in Rutland is described as a minor town which probably arose from an earlier military settlement, with its defences built during the 2nd century AD (Todd 1968, 17; Burnham and Wacher 1990, 130, 133). The town had hypocausts and a public bath, and comprised of a small-scale industrial and religious focus (Burnham and Wacher 1990, 133, 135). The entire settlement complex at Great Casterton encompassed the town, a *villa* and a Roman fort (Corder 1951, 1954; Todd 1968).

Excavations by Archaeological Solutions Limited in 2004 and 2005 at Great Casterton have exposed a total of 140 individuals from a cemetery of mid/late 3rd-4th century date (McConnell et al. 2012) (Fig. 4.19). The skeletal report by Phillips and Leach (2008) identified 48 non-adults (34.3%) with a marked dearth of perinates and infants. There are only three perinates in the sample, all of which have been recovered from multiple burials. One perinate was found within the pelvic cavity of an adult female, possibly implying birthing complications. Another perinate was placed in the arms of an adult female. Again, this may suggest complications during or shortly after birth. A peak in the age distribution across the cemetery at 1-5 years suggests a relationship between weaning and mortality (Phillips and Leach 2008).

Palaeopathological analysis of the non-adults revealed a range of conditions indicative of ill-health. Dental hygiene was poor as indicated by caries in 3.2% of all non-adult teeth. Dental enamel hypoplasia was observed in four non-adults, and endocranial lesions in five. Three non-adults exhibited diffuse and prolific lesions, likely to be the result of tuberculosis in two individuals and possible Langerhans Cell Histocytosis in one child (Phillips and Leach 2008).

The archive is currently curated at Rutland County Museum in Oakham, Rutland, where a total of 38 non-adult skeletons could be located and recorded upon re-analysis.

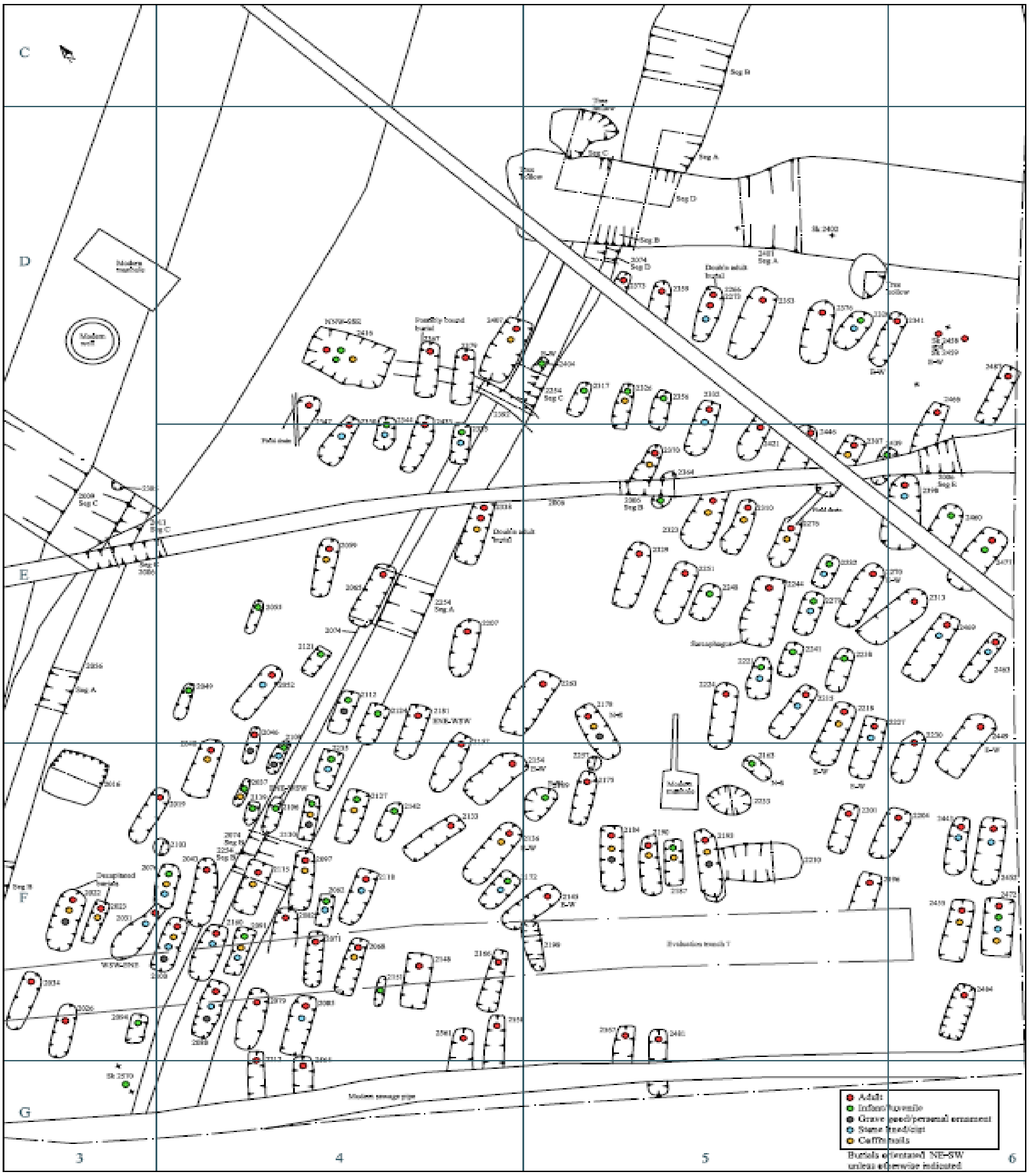


Figure 4.19. Plan of the cemetery at Great Casterton (reproduced with kind permission from Archaeological Solutions Limited)

4.1.4.6. Dunstable, Bedfordshire (3rd-5th century AD)

Durocobrivae is a Romano-British town south of modern-day Dunstable in Bedfordshire. The Roman town was set along the crossroads of two important Roman roads, Icknield Way and Watling Street, which fostered its function as a local centre for commerce and trade (Matthews 1981). Excavations between 1968 and 1980 by Manshead Archaeological Society have uncovered a Romano-British cemetery of 3rd-5th century date south of Dunstable. The cemetery is set outside of the Roman town in a ditch along the two Roman roads (Fig. 4.20).

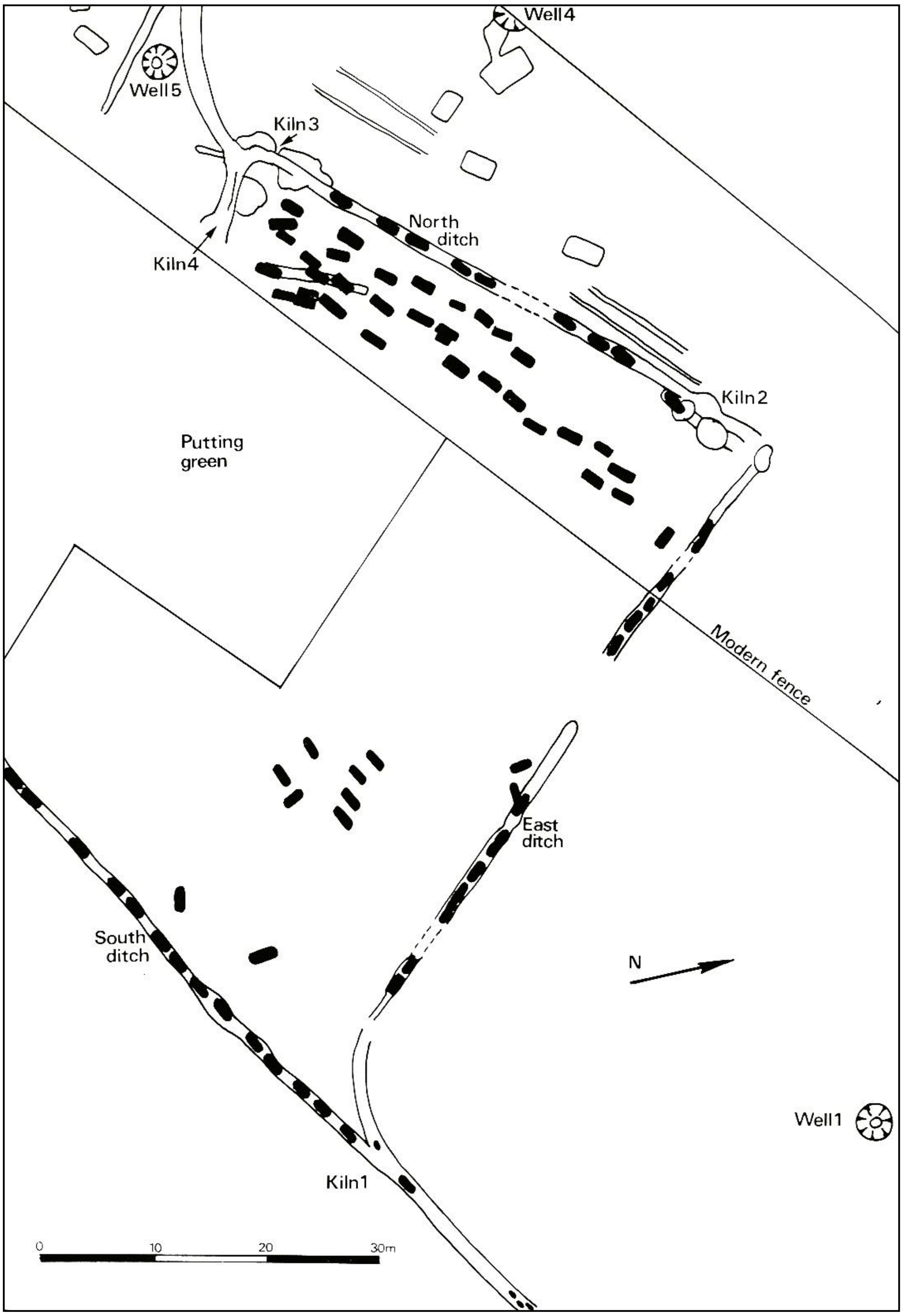


Figure 4.20. Plan of the Romano-British inhumations at Dunstable (from Matthews 1981, 4)

A total of 112 individuals were buried in formal graves, the cemetery ditch or surrounding wells and pits (Fig. 4.20). Decapitation did occur in 12 individuals, including an infant. Grave goods in the form of jewellery, glass and pottery were also present (Matthews 1981). The skeletal report includes individuals up until 19 years in the non-adult age category and lists 30 non-adult individuals (26.8%). Half of the non-adult assemblage comprises of infants (n=15), one of which was beheaded (Jones and Horne 1981, 37). The archive is currently held at Wardown Park Museum in Luton, and a total of 27 non-adults were located and recorded at the museum.

4.1.4.7. Springhead, Kent (1st-4th century AD)

Burnham and Wacher (1990, 192-193) described Roman Springhead, *Vagniacis*, as a small town. The site is located in Kent in a valley along the major provincial Roman road of Watling Street between London and Rochester. It is likely that the site had been associated with a religious function prior to its use as a Romano-British sanctuary centre. The religious complex was contained along the Roman road at the heart of the settlement and consisted of several shrines and temples, which date from the late 1st to the early 3rd century AD. Evidence for defences of the settlement has been found, which run along the north-eastern corner of the religious complex. The site may have held up to seven temples. Infant burials, including two decapitations, have been found in the corners of one of the two rooms of Temple IV, which are frequently referred to when discussing the religious foci at Springhead (Burnham and Wacher 1990, 193, 197).

The four infants recovered from Temple IV are discussed by Scott (1999, 86) and Penn (1960, 121-122). According to Penn (1960, 121), these infants are around 6 months old, and deposited in the corners of the temple structure as foundation burials. The burials had been laid down in two distinct events, separated by a ten year period. The exact dating of the burials remains difficult, but a 2nd century AD date is likely (Scott 1999, 86). The later burials in the upper floor are orientated along the eastern aspect of the building whereas the older burials in the lower floor occupy the corners of the western aspect. Two individuals are described as decapitated, the infant in the north-eastern corner of the later deposit, and the infant in the south-western corner of the earlier sequence (Penn 1960, 121). Unfortunately it was not possible to locate these infants at the time of study for re-analysis.

Later excavations at Springhead have yielded additional non-adult burials. Excavations undertaken in 1994 by Oxford Archaeology recovered the remains of 12 infants (Boyle and Early 1999, 1). The individuals were represented by disarticulated bones deposited in a range of 1st and 2nd century AD contexts within the settlement boundaries (Boyle 1999, 34). Only three of the contexts yielded fairly complete skeletons, although no palaeopathological information was available, and the remainder was too fragmentary to include in the combined study sample.

Recent excavations by Oxford and Wessex Archaeology for the Channel Tunnel Rail Link in 2000-2003 have recovered a total of 104 Romano-British and 29 Anglo-Saxon inhumations from both the sanctuary complex (100 individuals) and the roadside settlement (33 individuals) (Figs. 4.21 and 4.22). An additional neonate burial was reported from a nearby *villa* complex at Northfleet (McKinley 2011, 8-9). The non-adults from the roadside settlement have been buried within the settlement boundaries (Fig. 4.21), with the majority of the Springhead adult population buried in the cemetery at Pepper Hill on the outskirts of the settlement (McKinley 2011, 8-9).

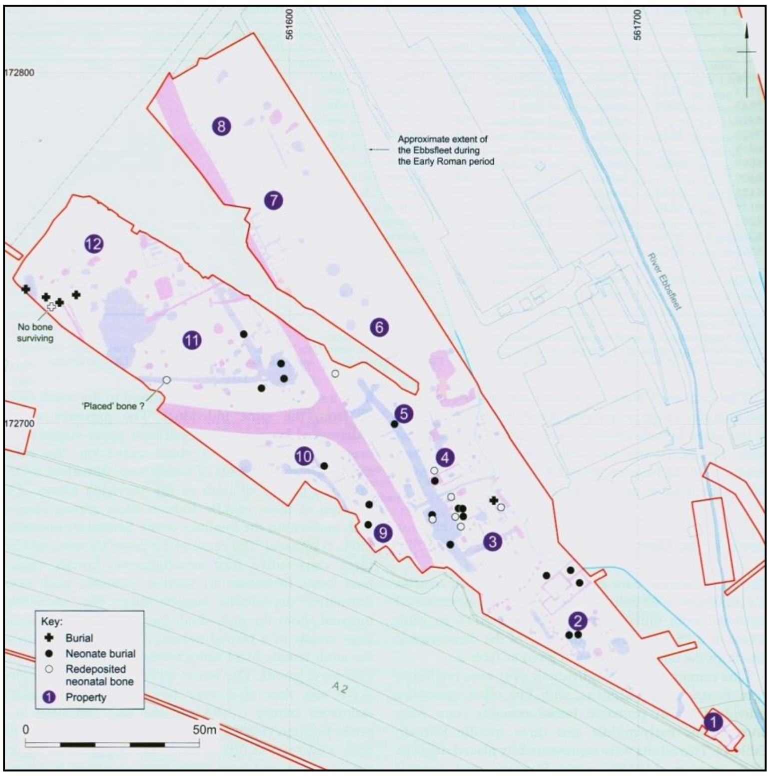


Figure 4.21. Distribution of intramural burials at Springhead roadside settlement (from McKinley 2011, 6)

A total of 82 non-adult individuals relating to the 1st-4th century AD contexts of the roadside settlement and sanctuary complex have been discussed in McKinley (2011). The non-adult sample mainly comprises of infants, with 40.8% aged under two months and 22.4% perinates. At least 39 infants have been redeposited. Another two infants have been buried in a vessel, and an additional two infants have been interred as a double burial. Pathological bony changes were found in three individuals, with one case of cribra orbitalia and two instances of periosteal new bone formation on cranial elements. The neonate recovered from the *villa* complex was deposited in a posthole and displayed one 'expanded' sternal rib end (McKinley 2011, 14), which may be pathological in origin. The osteological data on the Springhead non-adults was extracted from the report and included in the combined study sample, as the remains have been reburied and are no longer available for analysis.

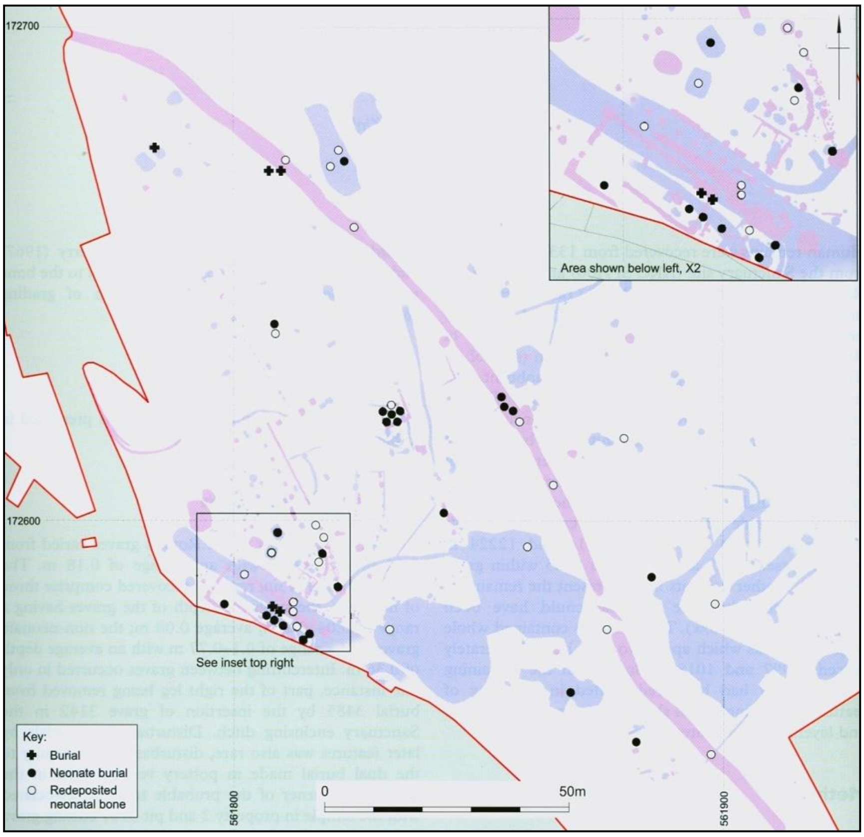


Figure 4.22. Distribution of burials in the Springhead sanctuary complex (from McKinley 2011, 2)

4.1.4.8. Chesterton, Cambridgeshire (3rd-5th century AD)

The late Roman cemetery at Chesteron in Cambridgeshire is linked to *Durobrivae*, a Roman town near Peterborough (Mackreth 1995) (Fig. 4.23). The cemetery was excavated by the Cambridgeshire County Council Archaeological Field Unit in 1998 as part of a rescue project and the site archive is managed by the Cambridge Antiquarian Society. The burial ground was in use from the 3rd through to the 5th century AD and appears to have been disturbed upon excavation. Individuals recovered are of all ages and sexes, 57 in total, with nine (15.8%) non-adults which were included in the combined study sample. Three non-adults were interred with adult individuals. Grave alignment is not uniform, ranging from north-south to east-west. The difference in alignment may stem from separate groups of burials but is also influenced by the western bank of the urban defences of the town, as well as the Roman road into the town (Hatton and Wall 2006).

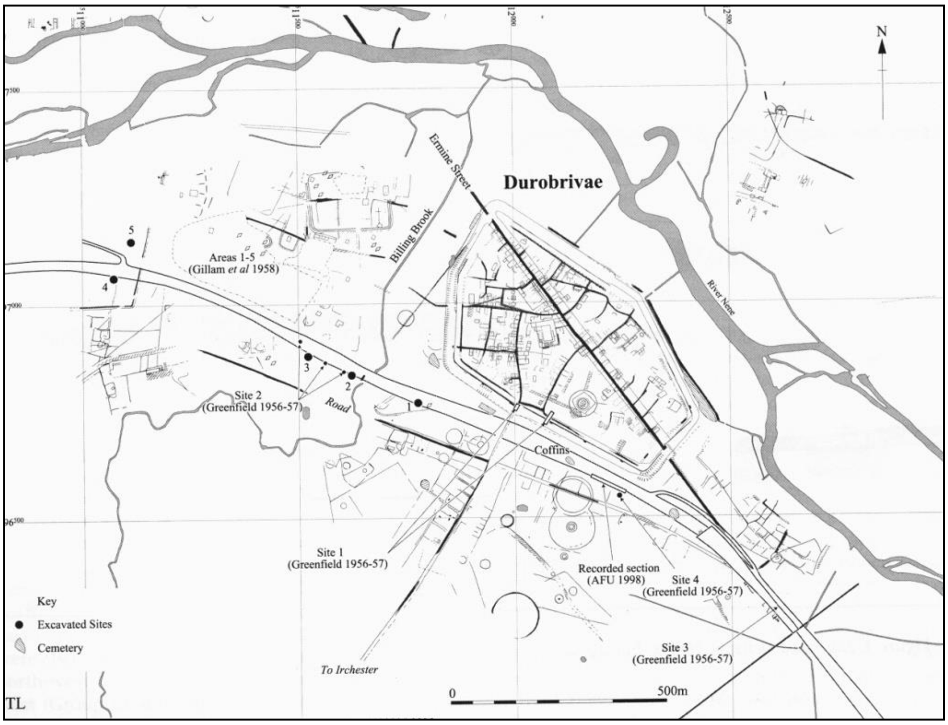


Figure 4.23. Plan of Roman Durobrivae and location of excavations (from Hatton and Wall 2006, 7)

There was evidence for wooden coffins, and two individuals were buried in stone coffins. Graves were mostly unfurnished, bar one child burial with copper alloy, ivory, amber and glass adornments (Hatton and Wall 2006). Fragmentation was high and no complete inhumations were recovered. Pathological conditions are mainly limited to dental disease and degeneration in adult skeletons, no skeletal markers of pathologies were recorded in the non-adults (Duhig 2006, 14-15).

4.1.5. The rural sites

Non-adults from 11 rural burial grounds have been included. Skeletal data was extracted from site reports for the burials from Frocester, Watersmeet, Babraham Institute, Huntsman's Quarry, Dorcherster-by-pass, Dewlish *villa* and Bantycock Mine, and included in the combined study sample. Primary skeletal data was recorded by the author for the non-adults from Cannington, Bradley Hill, Owslebury and Catsgore (Fig. 4.1). The sites are listed according to the total number of skeletons reported in their respective archives.

4.1.5.1. Cannington, Somerset (3rd-4th century AD)

Cannington is a rural multi-period site in Somerset near Bridgwater in southwest England, showing occupation from the Iron Age through to the Anglo-Saxon period. The site is situated in close proximity to the Bristol Channel and the estuary of the river Parrett. A Roman road ran between the close-by Roman port of Combwich and Ilchester, with Cannington set along the road (Rahtz et al. 2000, 7-9).

The site was excavated in 1962 and 1963 by Philipp Rahtz and volunteers, supported by the Ministry of Public Building and Works (Rahtz et al. 2000). Rahtz et al. (2000, 59) stated that the excavations uncovered the burials of 542 individuals, with 155 non-adults (28.6%) (Figs. 4.24 and 4.25).

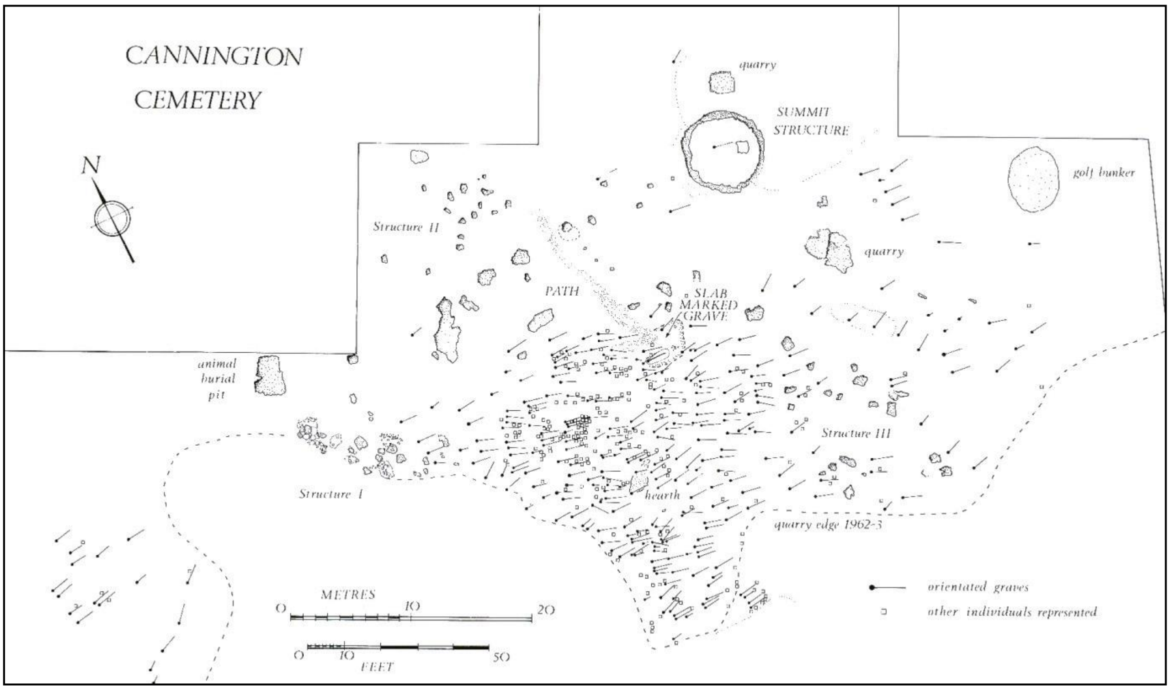


Figure 4.24. Map of the Cannington site cemetery (from Rahtz et al. 2000, 30)

Four children and one neonate were interred with grave goods, ranging from fragments of pot to items of jewellery, there are however some discrepancies with the dating of some of these burials and they may fall into periods later than the 5th century AD (Rahtz et al. 2000, 85, 92). The authors also note possible family plots due to the arrangement of burials within the cemetery, and the diverse cultural influences that have acted upon it, including Roman, pagan, Christian and Anglo-Saxon rites (Rahtz 2000, 108). Characteristic of late Roman cemeteries, west-east alignment is prevalent (Rahtz et al. 2000, 410).

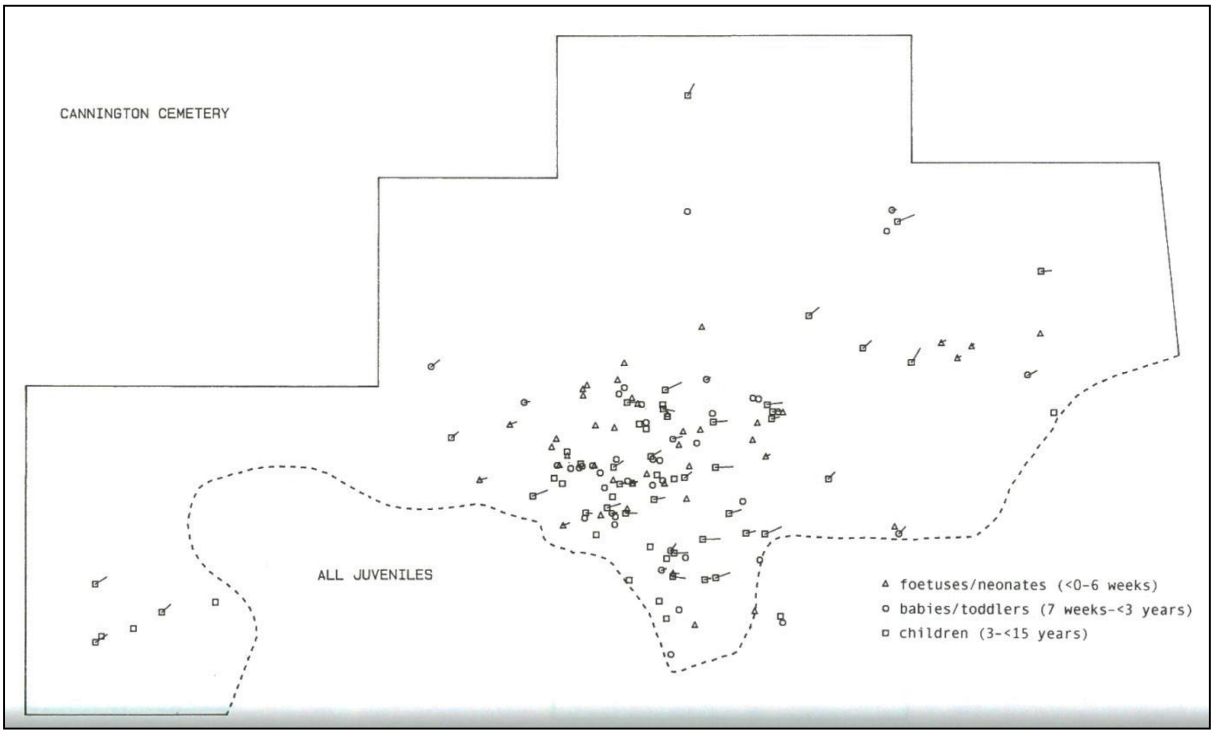


Figure 4.25. Distribution of non-adult burials across the Cannington cemetery site (from Rahtz et al. 2000, 68)

Rahtz et al. (2000, 409) also claim to have found a correlation between depth of the grave and status within society, inferring that males have the deepest graves and highest social standing and infants are found on the opposite end of the scale in both realms. Brothwell et al. (2000a, 207-208) reported a healed greenstick fracture in a 9-year old, which is one of the few cases of reported non-adult trauma in Roman Britain. A total of 148 non-adult skeletons were located and recorded at the Natural History Museum, London.

4.1.5.2. Watersmeet, Cambridgeshire (4th-5th century AD)

A late Roman cemetery at Watersmeet, Mill Common, Huntingdon in Cambridgeshire was excavated by Archaeological Solutions Limited in 2003 and revealed the remains of 72 individuals with 14 non-adults (19.4%), which were included in the combined study sample. Although the Roman town of *Durovigutum*, modern Godmanchester, is in close vicinity, this cemetery relates to a Roman *villa* and small Roman enclosure nearby (Nicholson 2006) (Fig. 4.26).

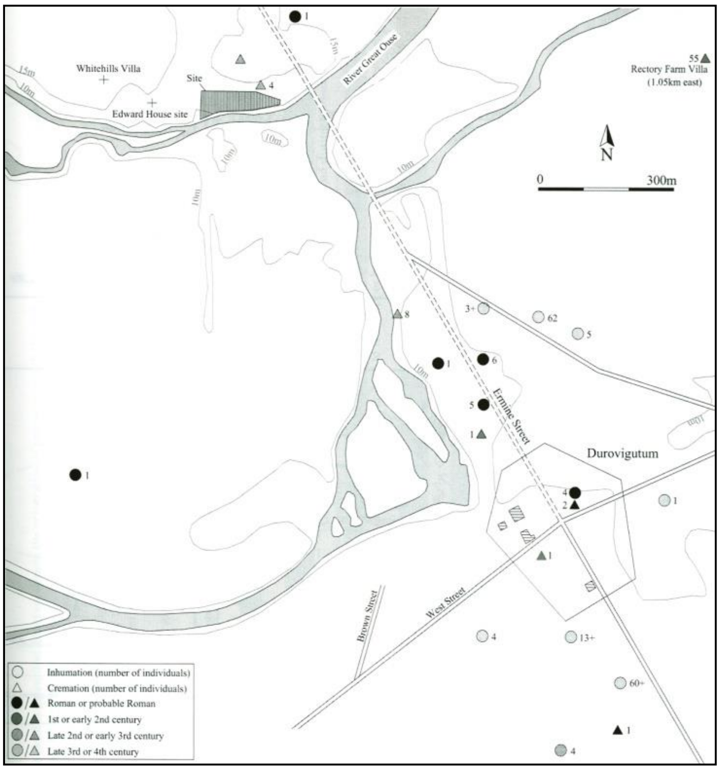


Figure 4.26. The site at Watersmeet and other Roman burials in the Godmanchester area (from Nicholson 2006, 59)

The burials were divided among the main cemetery area and four outlying burials in the field ditches. All of the non-adults were recovered from the main cemetery (Fig. 4.27). The site archive is currently deposited at the Cambridgeshire Archaeology Store. Individuals were buried in a supine position, mostly aligned west-southwest to east-northeast. Grave goods were only present in two adult inhumations (Nicholson 2006). Preservation was extremely poor, with the majority of skeletons being preserved to 50% or less (Phillips 2006, 75). Osteological analysis of the remains has been undertaken and showed two incidences of pathology in non-adults, enamel hypoplasia in a 10-15-year old and cribra orbitalia in a 10-year old (Phillips 2006, 79, 81). Unfortunately no further information is provided on the extent and severity of the lesions. The assemblage as a whole is characterised by poor dental health and a relatively high frequency of osteoarthritic skeletal changes. The observed pathologies were interpreted as the result of a diet high in carbohydrates, and a heavy workload resulting in degenerative joint disease, indicating that the cemetery population were the workforce of the nearby *villa* estate (Phillips 2006, 82).

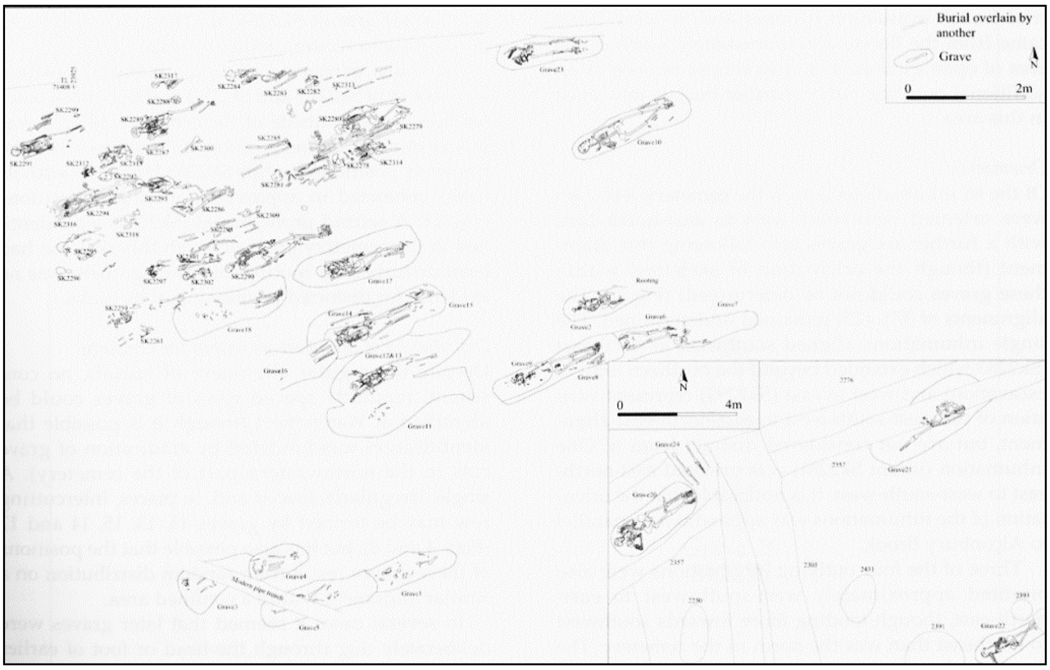


Figure 4.27. The cemetery site at Watersmeet (from Nicholson 2006, 65)

4.1.5.3. <u>Frocester, Gloucestershire (3rd-5th century AD)</u>

Frocester is a Romano-British rural settlement in Gloucestershire, south-west of Stroud. The site exhibits evidence for continuous occupation from the Neolithic. Romano-British Frocester consisted of a cluster of three distinct village sites and associated farmsteads (Price 2000a,b). The Romano-British settlement was excavated between 1995 and 1998 as part of a larger project exploring the archaeology of this multi-period site (Price 2000a, 3) (Fig. 4.28). The excavations were undertaken by Eddie Price himself and volunteers with the Gloucester and District Archaeological Research Group (Price 2000a).

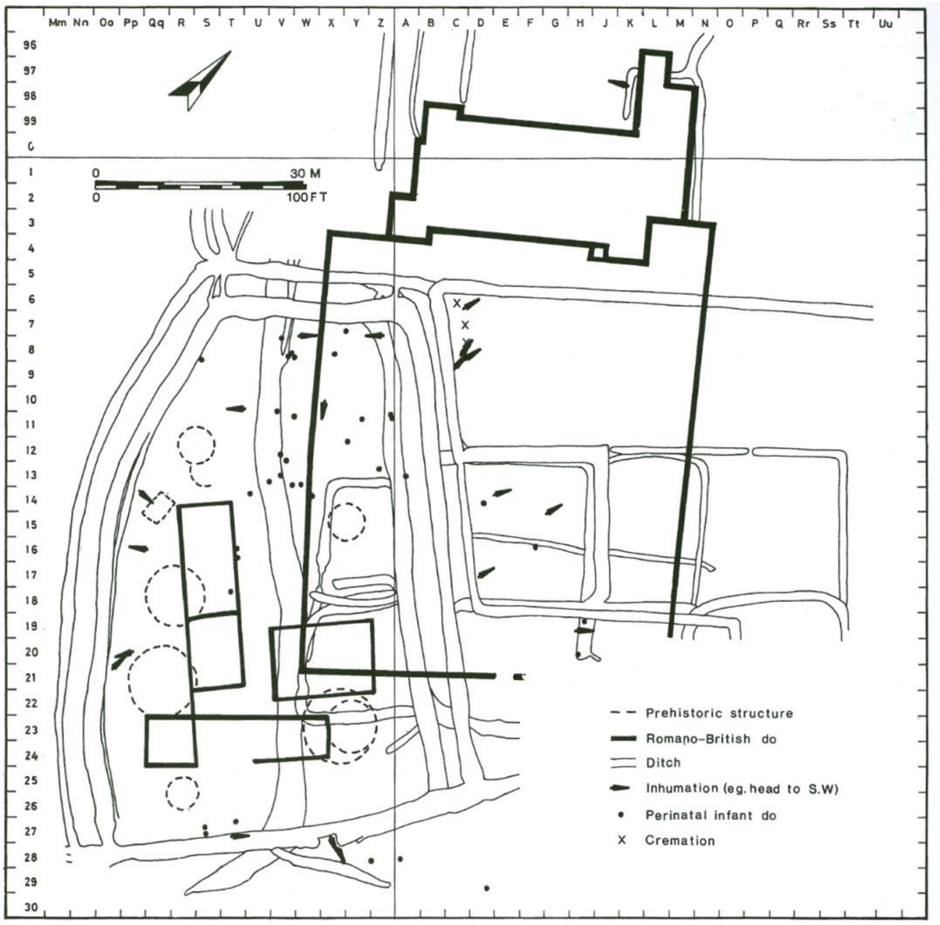


Figure 4.28. Distribution of inhumations and cremations at Frocester (from Price 2000a, 204)

A total of 62 individuals were recovered from 60 graves of 3rd-5th century AD date. The non-adults form the majority of the sample, with 43 individuals (69.4%), 37 of which are infants (86.0%) (Reece 2000a, 205). Unfortunately, the infant burials were excluded from osteological analysis, and the palaeopathology of the remaining six non-adults was limited to one case with evidence for an 'enlarged skull and abnormal teeth' (Reece 2000a, 203-206). The Frocester skeletal archive has been reburied (Cock 2013 pers. comm.). Only osteological data extracted from the skeletal report was therefore available for discussion in the combined study sample.

4.1.5.4. Bradley Hill, Somerset (4th-5th century AD)

The Romano-British site at Bradley Hill in Somerset consists of a small farmstead with three buildings. The site shows evidence for earlier occupation from the Iron Age to the end of the 1st century AD. The Romano-British farmstead and associated cemetery date to the late 4th and 5th centuries and have been excavated by the Western Archaeological Trust between 1968 and 1972 (Leech et al. 1981; Gerrard 2011).

A total of 55 individuals were buried, both in the cemetery, as well as within, or in close proximity to buildings of the farmstead, including 34 infants and one child (63.6%) (Everton and Leech 1981, 195). Most notably, a cluster of 21 infant burials was found associated with a building interpreted to have served as an animal shed (Fig. 4.29).

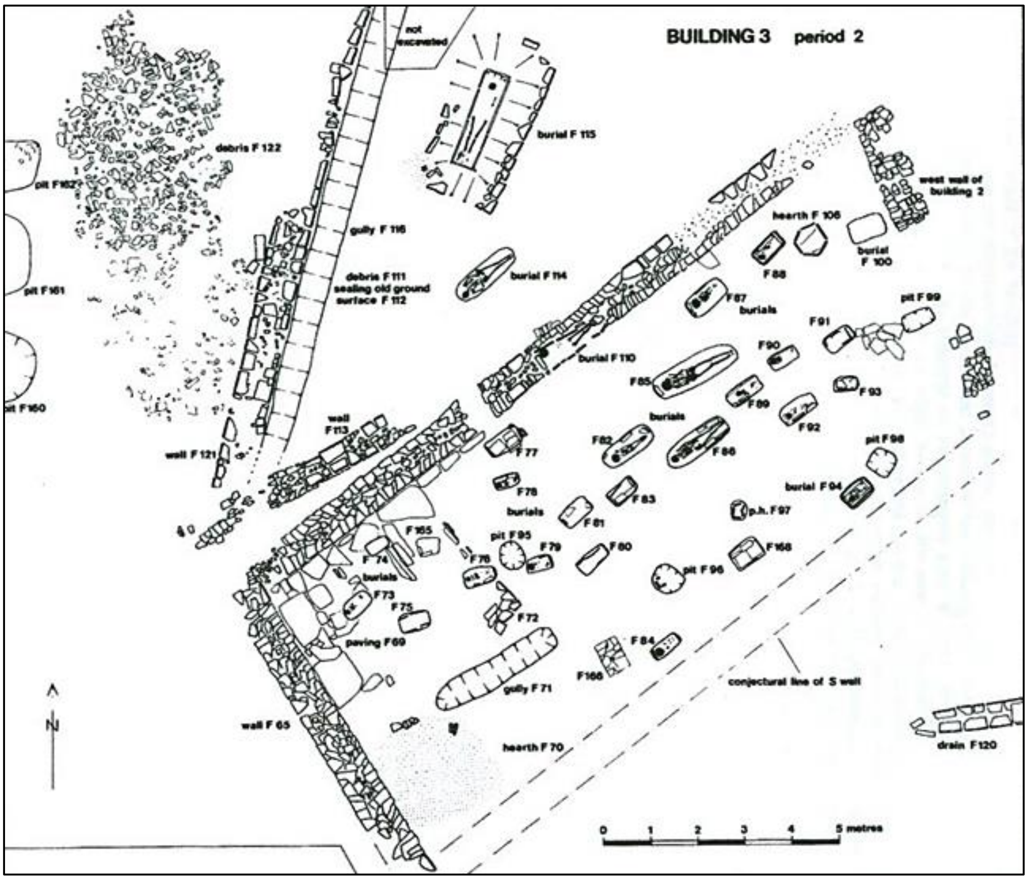


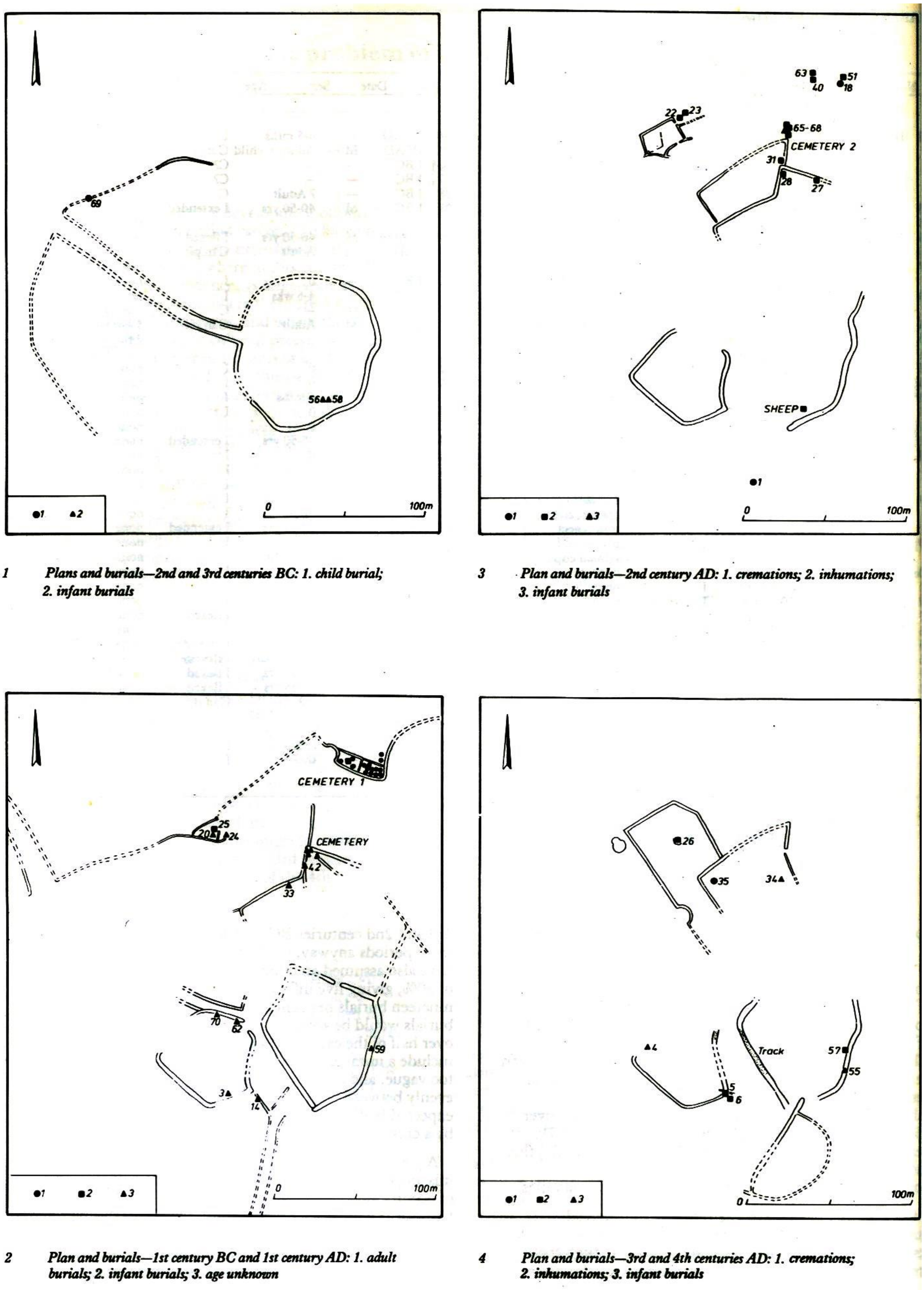
Figure 4.29. Non-adult burials at Bradley Hill associated with Building 3 (from Leech et al. 1981, 190)

The infants were buried in stone cists with covering slabs, aligned south-west to north-east with their heads towards the west. Other singular or triple burials of infants were also contained within the settlement boundaries (Leech et al. 1981). Two adult burials of the cemetery to the south of the site have been radiocarbon-dated to the 5th century which has been interpreted as completely ruling out a Roman use of the cemetery (Gerrard 2011). However, the cluster of infant burials in Building 3 dates to the late 4th century (Leech et al. 1981). It is argued that the cemetery progressively moved away from the buildings and towards the south, over the period of occupation originating in the late Roman period (Gerrard 2005). The skeletal archive is currently housed at Somerset Heritage Service in Taunton, where 29 non-adult individuals were recorded.

4.1.5.5. Owslebury, Hampshire (1st-4th century AD)

Bottom Pond Farm at Owslebury, five miles south-east of Winchester was a Romano-British farmstead in Hampshire. Occupation of the site spanned the Iron Age through to the post-Roman period (Collis 1975). The site had been excavated under the direction of Professor John Collis (University of Sheffield) between 1963 and 1972 and yielded a total of 49 burials, with 32 infants dating from the Iron Age to the late Roman period (Collis 1977, 27; Nystrom and Swales in press). According to Collis (1977, 26) the site consisted of a single farm, rather than a whole village, and is mainly characterised by a complex of ditches. Although there is no formal cemetery as such, three clusters of burials have been identified (Fig. 4.30).

The majority of the infant burials were located within the settlement boundaries (Collis 1968) (Fig. 4.30). The non-adult remains dating to Romano-British contexts comprise of one adolescent from the main burial ground and 15 infants and young children (32.7%). The forthcoming report by Nystrom and Swales (in press) suggests some instances of metabolic disease. All 16 Roman non-adults were located and re-recorded at the store of Hampshire Arts and Museums Service in Winchester.



1 Plans and burials—2nd and 3rd centuries BC: 1. child burial; 2. infant burials

3 Plan and burials—2nd century AD: 1. cremations; 2. inhumations; 3. infant burials

2 Plan and burials—1st century BC and 1st century AD: 1. adult burials; 2. infant burials; 3. age unknown

4 Plan and burials—3rd and 4th centuries AD: 1. cremations; 2. inhumations; 3. infant burials

Figure 4.30. Roman Owslebury burial plan (from Collis 1977, 28)

4.1.5.6. Babraham Institute, Cambridgeshire (2nd-4th century AD)

The Roman cemetery at Babraham Institute was excavated in 2006 by Cambridge Archaeological Unit of the University of Cambridge who also hold the skeletal archive. The project uncovered the skeletal remains of at least 42 individuals from 36 2nd-4th century AD burial contexts. Among the skeletons are 12 non-adult skeletons (28.6%), which were included in the combined study sample. The inhumation cemetery is orientated along a nearby Roman road and relates to an earlier Romano-British cremation cemetery (Fig. 4.31). The burial grounds are believed to have served the hinterland of Babraham with farmsteads and small rural settlement compounds (Timberlake et al. 2007). Graves showed mixed alignment, limited use of coffins and a relatively high frequency of grave goods. Four of the 12 non-adult burials contained adornments or pottery (Timberlake et al. 2007).

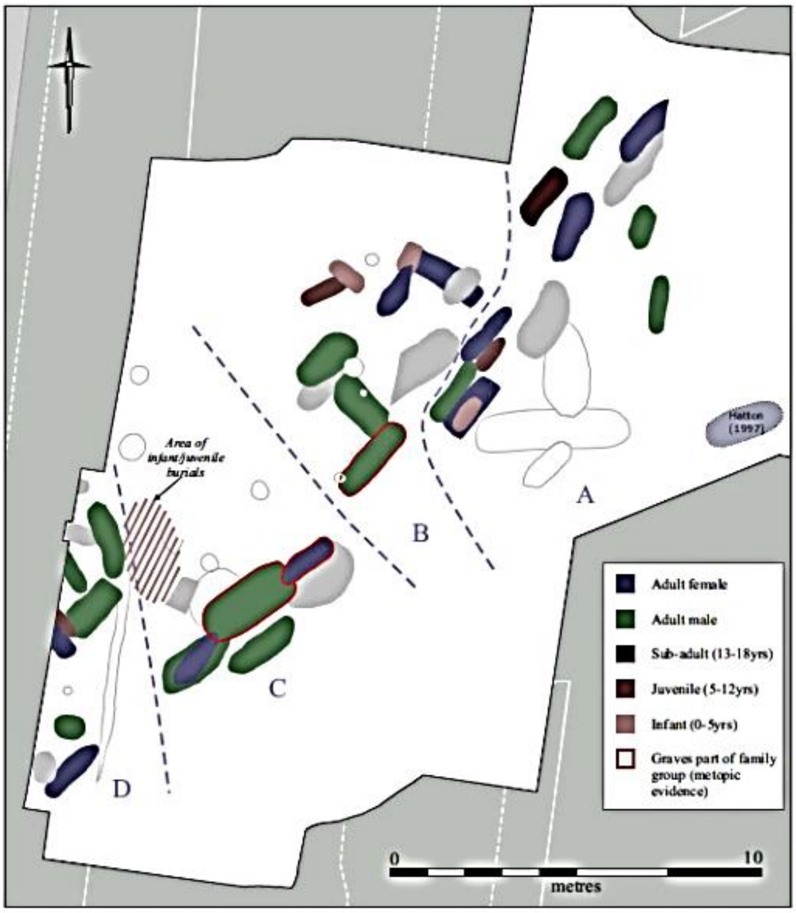


Figure 4.31. The Romano-British cemetery at Babraham Institute (from Timberlake et al. 2007, 50)

A discussion of pathologies was largely limited to the adult population. However two adolescent males were decapitated and buried with the head placed either between the feet or abutting the legs (Timberlake et al. 2007). The skeleton of a 14-17-year old who was decapitated exhibited cut marks on the clavicle, possibly associated with the removal of the head. The same individual also showed a mid-shaft fracture to the left tibia, which was well healed but poorly aligned (Dodwell 2007, 114).

4.1.5.7. Dorchester By-pass, Dorset (4th century AD)

The excavations along the Dorchester By-pass, Dorset revealed two burial grounds along Maiden Castle Road, Southern By-pass, and the A37 Western Link Road (Smith et al. 1997). The excavations were undertaken as a joint effort between the Dorset Natural History and Archaeological Society, the Dorset Archaeological Committee, the Dorchester Excavation Committee and Wessex Archaeology. The site archive is currently deposited at Dorset County Museum in Dorchester (Smith et al. 1997, 13). The wider excavation area has been occupied from the Neolithic through to the Roman period (Smith et al. 1997, 3).

The site at Maiden Castle Road along the Southern By-pass relates to a small Romano-British rural settlement (Smith et al. 1997, 56). The cemetery was situated to the north of the Romano-British features and the graves were aligned either east-west or north-south (Fig. 4.32). Non-adults burials were exclusively oriented along the east-west axis. Evidence for a coffin was found in most burials, some of which also contained grave goods. Only one non-adult burial was furnished, a young child with a perforated chalk object (Smith et al. 1997, 56, 64-66). The excavation of the cemetery uncovered 19 graves with 22 individuals, six of which were non-adults (27.3%); these were incorporated in the combined study sample. The individuals were recorded by Rogers (1997, 156-157) with information on age, sex, stature and pathologies.

The burial ground at the A37 Western Link Road had been in use from the Late Iron Age to the Late Roman period. The middle to later Roman burials were located to the south of the excavated site and amount to five with three non-adults (60.0%). The graves relate to an in-filled ditch and are likely to signify a separate burial cluster. Alignment of these burials deviates from the east-west axis. Three of the five individuals were buried flexed and lying on the side, found with hobnails, coffin nails or cattle bones. Two of the non-adults were buried in a coffin (Smith et al. 1997, 212, 214-215). The skeletons have been recorded and analysed by Jenkins (1997, 254-256), and the data was directly used for the combined study sample.

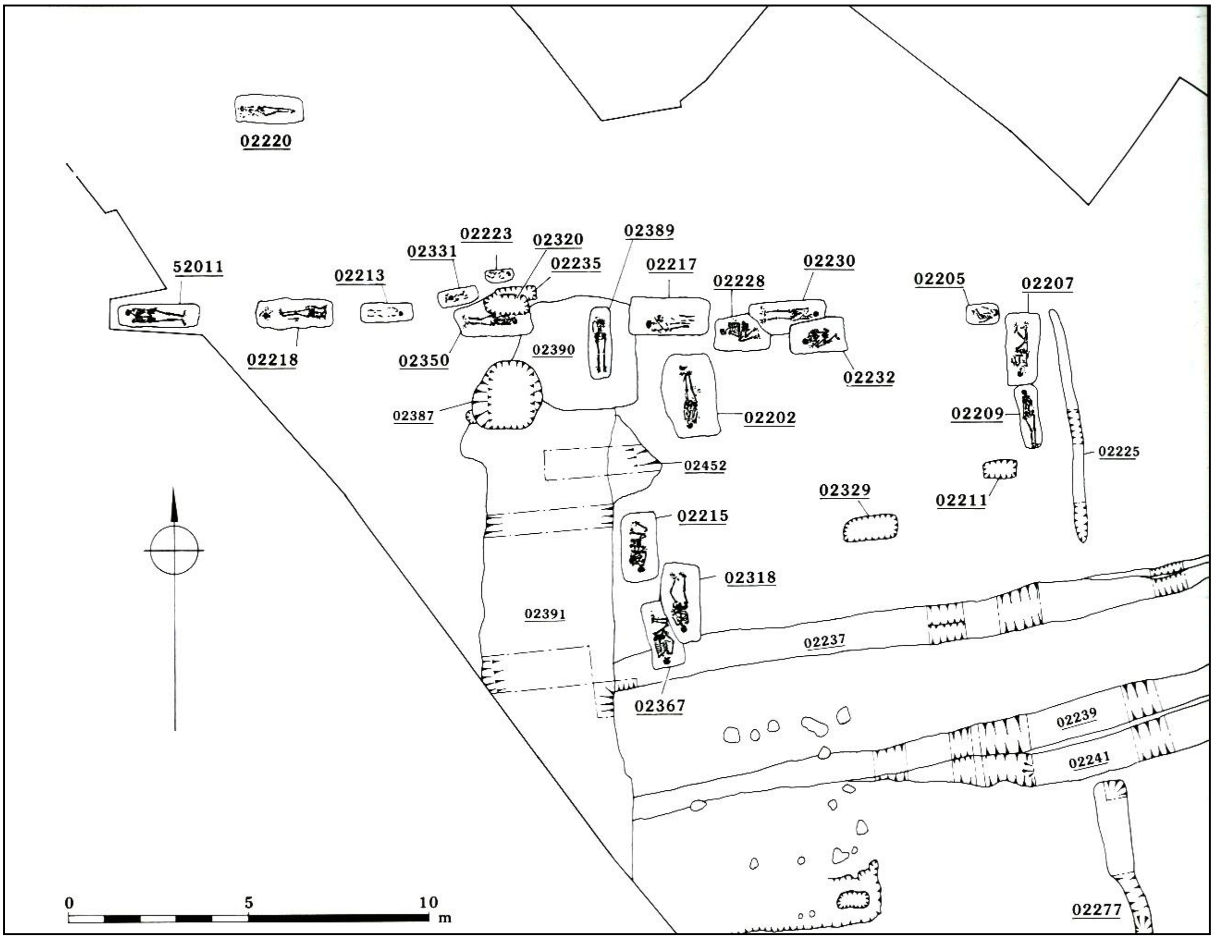


Figure 4.32. The late Roman inhumation cemetery at Maiden Castle Road (from Smith et al. 1997, 64)

4.1.5.8. Catsgore, Somerset (2nd-5th century AD)

Catsgore is a small Romano-British village in Somerset. The village was excavated between 1970 and 1973 by Yeovil Archaeological and Local History Society, who found evidence for at least 37 building structures. The village would have consisted of at least five, probably up to 12 separate farms dating to the 2nd to 5th century AD (Leech 1982, 1) (Fig. 4.33).

A total of 26 burials were recovered from within the settlement boundaries, 23 of which were non-adults (88.5%), including 20 infants, two children and one adolescent (Everton 1982, 147). Most of these burials have been recovered from within building structures associated with either living accommodation or an agricultural function, with two burials found under the eaves of houses (Everton 1982, 13-33). Palaeopathological information in the site report is restricted to the adult burials only (Everton 1982, 148). The skeletal archive for Catsgore is currently held at Somerset Heritage Service in Taunton, where 15 non-adult individuals were re-recorded.

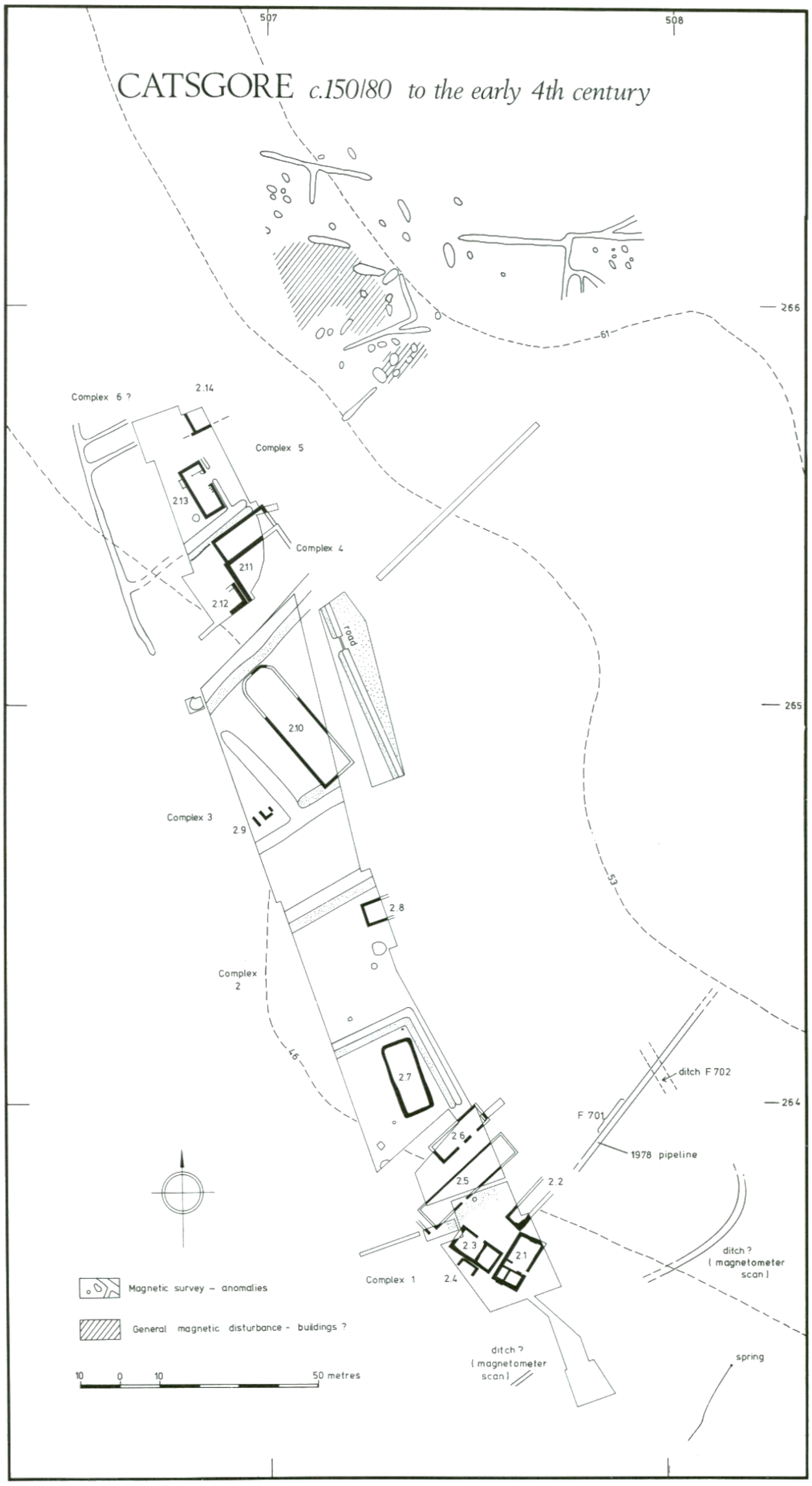


Figure 4.33. Plan of the farm complexes at Catsgore from the 2nd-4th century AD (from Leech 1982, 6)

4.1.5.9. <u>Bantycock Gypsum Mine, Nottinghamshire (2nd-4th century AD)</u>

A small Romano-British cemetery at Bantycock Mine, near Newark, Nottinghamshire was excavated in 2005 by Pre-Construct Archaeological Services. The burial ground relates to a small rural 2nd-4th century AD settlement in a generally well populated area of Roman Britain, characterised by farmsteads and villages (Pre-Construct Archaeological Services 2006). The site held a total of 24 individuals, with seven non-adults (29.2%) incorporated in the combined study sample, all of which were contained within the same heterogenous burial space (Fig. 4.34). It is, however, of note that the non-adults are either in the infant or adolescent age categories. The remains of a foetus were recovered from the abdominal cavity of an adult female. No pathology was reported in the non-adults (Keal 2008). The skeletal archive is currently held at Pre-Construct Archaeological Services in Saxilby, Lincolnshire.

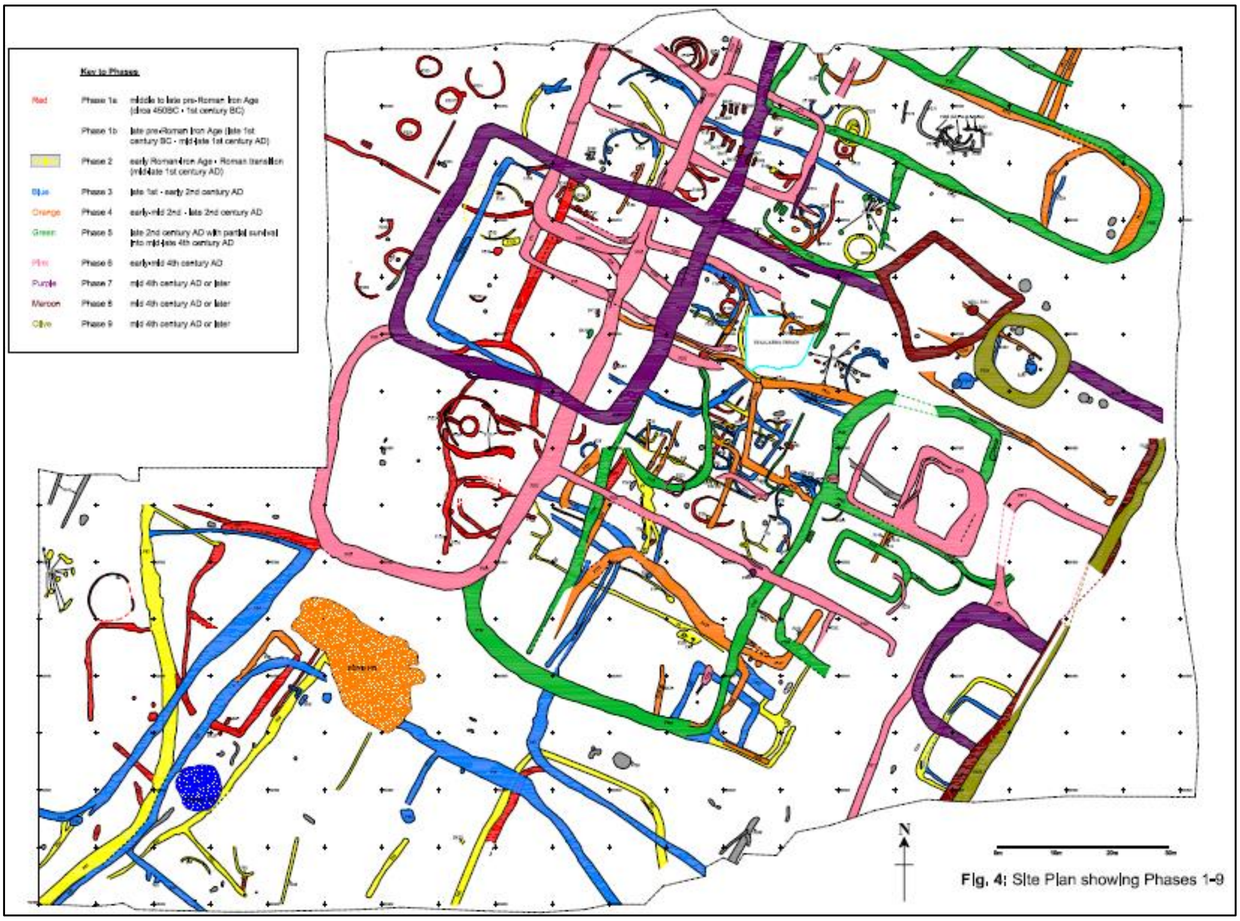


Figure 4.34. Site plan of the phases excavated at Bantycock Gypsum Mine. The skeletons are marked in maroon at the northern part of the site (reproduced with kind permission from Pre-construct Archaeological Services)

4.1.5.10. Huntsman's Quarry, Gloucestershire (2nd-3rd century AD)

The Romano-British cemetery at Huntsman's Quarry, Naunton, Gloucestershire dates to the 2nd and 3rd century AD and served a farmstead. The site which shows evidence for continuous occupation since the Iron Age had been subject to excavations and watching briefs between 1994 and 1996 by Patrick Foster Associates (Gowans and Pouncett 2000) (Fig. 4.35).

The burials were scattered across the site with infants mainly deposited in pits as multiple burial clusters or double burials. A total of 23 individuals have been excavated in 1994 and 1995, including 12 non-adults (52.2%), included in the combined study sample (Cherryson et al. 2000, 1). The 12 non-adults are mainly of perinatal age (n=10), with one infant below 6 months and a young child aged around 18 months (Cherryson et al. 2000, 2). The archive is currently held at the University of Southampton.

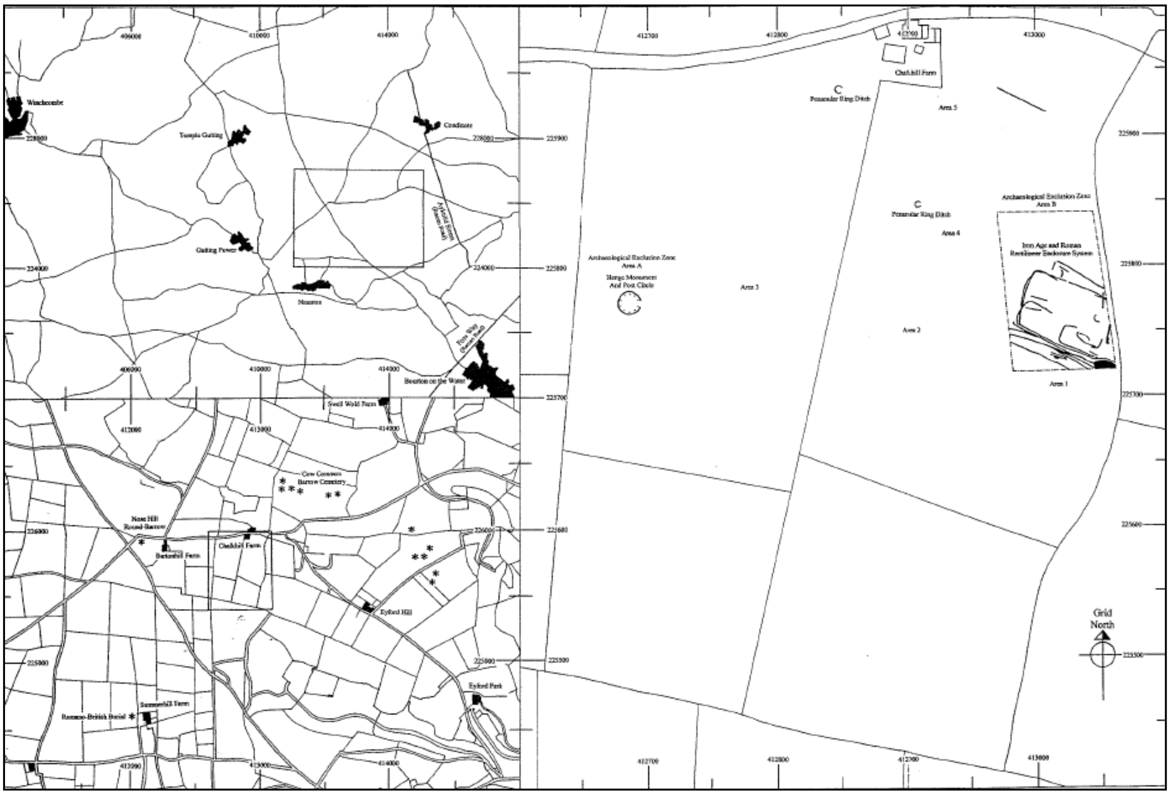


Figure 4.35. Site plan of the Iron Age and Roman features at Huntsman's Quarry (from Gowans and Pouncett 2000, 63)

4.2.5.11. Dewlish Roman *villa*, Dorset (4th century AD)

Dewlish Roman *villa* is located near Puddletown, Dorset and has been excavated between 1968-1979 by Bill Putnam and Weymouth College of Education (Putnam 1970). The excavations revealed a small farm, likely to have qualified as a *villa* in the 3rd century AD, which was gradually converted and expanded throughout the 4th century (Putnam 2007, 97). The remains of eight non-adults, used in the combined study sample, were recovered from the *villa* site and are currently held at Bournemouth University (Rohnbogner 2010). The burials stem from three distinct areas of the *villa* complex. A single inhumation and that of two infants were excavated from within the domestic grounds of the *villa*, in room 5 and room 8 (Fig. 4.36). A third burial comprising of three perinates and two young children was found within a barn or structure initially associated with an agricultural function, room 33 (Fig 4.36). However a shrine was later built over this structure (Hewitt 2012).

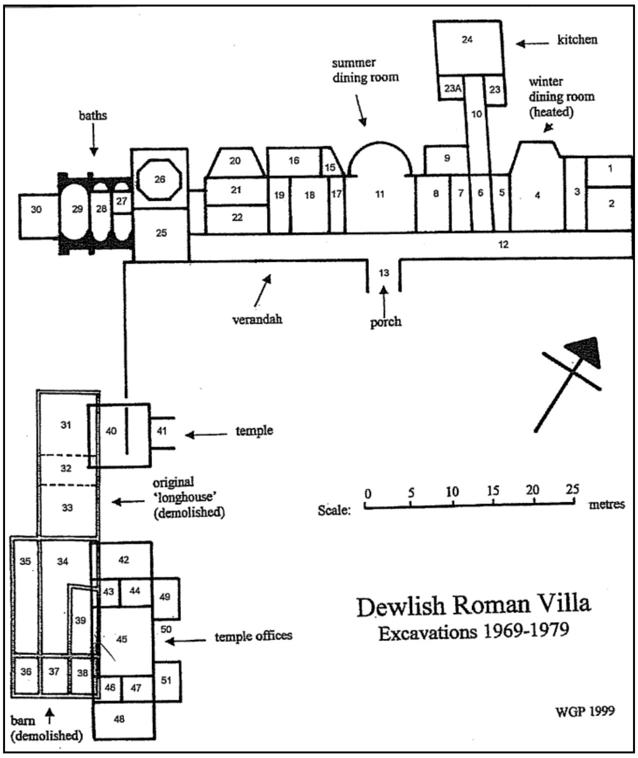


Figure 4.36. Plan of Dewlish Roman Villa (from Putnam 2007, 99)

4.2. METHODS

4.2.1. Introduction

Non-adults were defined as individuals aged between birth to 17 years old. The following age categories defined by Lewis (2002b,c) were used: perinate (around 38-40 weeks gestation), 0-0.5 years, 0.6-1.0 years, 1.1-2.5 years, 2.6-6.5 years, 6.6-10.5 years, 10.6-14.5 years, 14.6-17.0 years. It is recognised that the age ranges used do not reflect milestones of Roman child socialisation, but it was considered more fruitful to minimise age estimation error, and to allow cross-site comparison. The use of broad age categories rather than mean ages will minimise inter- and intra-population variability in skeletal maturation, and follows important biological landmarks of a child's development, such as birth, infancy, and adolescence (Lampl and Johnston 1996; Scheuer and Black 2004, 5-7; Lewis 2010). The selected skeletal ageing methods were based on assessing physiological age and correlating developmental stages with chronological age.

Researchers use a variety of different terms to describe the period of childhood. Here, perinates were considered full-term when aged between 38-40 weeks, as children born prior to 37 weeks have severely reduced chances of survival, even with modern medical intervention, and therefore would have been unlikely to survive in the past (Swamy et al. 2008). 'Neonate' was used for children up to one month (Lewis 2007, 2) and post-neonate for non-adults of one month to one year. The term 'infant' was only used for those aged from birth up to one year, which is in keeping with the clinical literature (Scheuer and Black 2004, 6). 'Child' broadly refers to the ages of one to 14.5 years, and those aged 14.6 to 17 years were referred to as 'adolescent'. No systematic sexing of the non-adults was undertaken, as sex determination in immature skeletons is notoriously fraught with difficulty. A note on sex was however made for adolescent skeletons.

4.2.2. Age-at-death

4.2.2.1. Perinatal ageing

4.2.2.1.1. Diaphyseal lengths

Long bone length is a product of skeletal maturation, development and growth and therefore correlates with chronological age (Fazekas and Kosa 1978, Scheuer et al. 1980). To ensure accuracy, diaphyseal length measurements (mm) were taken twice and the mean recorded. Measurements from all undamaged long bones of both left and right were taken. Diaphyseal lengths of the femur, tibia, humerus, radius and ulna were then used in Scheuer et al.'s (1980) linear regression formulae to obtain gestational age in weeks. Scheuer et al. (1980) used radiographs from a known sample of British foetuses and perinates for linear and logarithmic regression of long bone lengths for chronological age. Linear rather than logarithmic regression was chosen due to it being the simpler method whilst yielding results that are not significantly less accurate than those obtained using logarithmic regression (Scheuer et al. 1980).

4.2.2.1.2. Pars petrosa and ilia

If metric analysis of the long bones was not feasible, the maximum width and length of the pars petrosa or ilia were measured (mm) and ages derived using Fazekas and Kosa (1978). Although recognised as a problematic method due to the use of foetuses of unknown age, it was considered important for an age estimate to be made for all perinates. For infants and Molleson and Cox's (1993) maximum length and width measurements (mm) for the ilium were used to estimate age. The iliac dimensions and associated age ranges are based on dry bone measurements of 36 non-adults from the documented post-medieval cemetery at Christ Church, Spitalfields in London.

4.2.2.1.3. Pars basilaris and pars lateralis

When available, measurements of the maximum width and length of the pars basilaris and pars lateralis of the occipital bone were used to estimate age according to Scheuer and MacLaughlin-Black (1994). In infants younger than three months, the sagittal length of the pars basiliaris is greater than the maximum width, whereas in infants and children over five months, the pars basilaris is wider than it is long along its sagittal plane.

Around the seventh gestational month, both the pars basilaris and pars lateralis are approximately the same length. After about seven months in utero, the pars lateralis is then longer than the pars basilaris (Scheuer and Black 2000, 57-58).

4.2.2.1.4. Skeletal maturation

Fusion patterns in the sphenoid and temporal bone were used for deriving age ranges during the late foetal period and early infancy. Scheuer and Black (2000) and Schaefer et al. (2009) were consulted for fusion times. Scheuer and Black's (2000) and subsequently Schaefer et al.'s (2009) descriptions of early skeletal development are based on studies of modern known-age embryos, which have been examined radiologically, or in dissections and histological sections (Scheuer and Black 2004, 8-9).

4.2.2.1.5. Dental ageing

Gestational age may also be determined using deciduous calcification (Lunt and Law 1974). The tooth crowns of pre-term and neonatal children are however small and fragile, contained in the open tooth crypts. The crowns are therefore frequently lost or damaged postmortem (Lewis 2007, 42). Other methods suggest radiographs or microscopic assessment (Huda and Bowman 1995; Nystrom and Ranta 2003). However, these were outside of the scope of macroscopic and metric observations used for this study.

4.2.2.2. <u>Non-adult ageing</u>

4.2.2.2.1 Dental ageing methods

Dental ageing is considered the most accurate method for non-adults (Hillson 1996, 146). Dental ageing encompasses tooth mineralisation and eruption which cover the entire spectrum of the non-adult lifespan from the initial deciduous to the mature permanent dentition (Scheuer and Black 2004, 16). Compared to skeletal maturation, dental development is less subject to external stressors such as nutritional and social factors, which will give a more objective age estimate (Conceicao and Cardoso 2011). Tooth formation processes also match chronological age more closely than other skeletal ageing techniques (Saunders 2000, 142). Dental development is however influenced by sex, with the dentition in girls maturing faster than in boys (Garn et al. 1958). Smith (1991) demonstrated a difference in up to one year for the timing of closure of the distal apex in the permanent mandibular canine. All unsexed non-adults were therefore assigned the mean age for the average male and female stages of dental development.

Moorrees et al. (1963a,b) provided a dental ageing method based on crown and root formation and resorption of mandibular deciduous and permanent teeth, and the permanent maxillary incisors. Moorrees et al. (1963a,b) based their standards of tooth formation and resorption times on a serial longitudinal radiographic study of 380 modern American children. Based on the development of the third molar after Moorrees et al. (1963a), an age above 17 years can be reasonably assigned once the root is complete but the apex open. As a result individuals older than strictly 17.0 years may be included in the adolescent age category. The average mean age was taken for the tooth development stages of all teeth observed per individual (see A3.2 and A3.3 in Appendix III). When observing completion of the apex of a tooth, the age observed may be applied as a minimum age, as it cannot be determined when the apex closed prior to death.

Buikstra and Ubelaker (1994, 51) also provide a dental development chart (from Ubelaker 1989), giving age ranges according to the sequence of tooth formation and eruption. It is crucial to distinguish between teeth erupting through the gum as opposed to the alveolar bone when discussing tooth eruption in skeletal populations (Haavikko 1970). Ubelaker’s (1989) dental chart was referred to only when Moorress et al.’s (1963a,b) method could not be followed macroscopically or radiographically. Although the chart is a recognised standard (Hillson 1996, 142; Scheuer and Black 2004, 176), it was solely used in exceptions where other ageing methods proved unfruitful. Ubelaker’s (1989) chart is originally based on Schour and Massler’s (1941) diagram for dental development. The provenance of their sample is unknown, but probably based on Logan and Kronfeld (1933) and Kronfeld (1935), who based some of their findings on observations of children with cleft palate or who died due to serious illness (Lunt and Law 1974, Smith 1991, 147). Ubelaker (1989) subsequently revised the Schour and Massler (1941) chart by broadening and adding age groups in order to fit the chart to an American Indian sample. Ubelaker’s (1989) chart therefore contains a mix of samples, some inaccurate and incompatible which renders the chart only applicable for exceptions.

4.2.2.2.2. Diaphyseal lengths

Maximum length of the diaphysis of the humerus, radius, ulna, femur and tibia were taken using an osteometric board to the nearest millimetre. In order to minimise measurement error each measurement (mm) was taken twice and the mean recorded, with measurements taken from either side when present:

$$\bar{X} = \frac{\sum x}{n}$$

Where x is the sum of measurement 1 and measurement 2.

Diaphyseal length was only taken when the bone shaft was intact with no postmortem damage to either metaphysis. Measurements of glued specimens were only taken when the bone was closely united and not at an angle. When the bone was fusing at either or both epiphyses, or the elements had been glued, and it was not possible to separate the diaphyses from the metaphyses due to curatorial measures, the length of the individual epiphysis was accounted for (Humphrey 1998). Epiphyseal lengths were then subtracted from the long bone length to provide diaphyseal length.

Ubelaker (1989) provides standards for age estimation using diaphyseal length based on the Arikara Amerindian population from Dakota. Ubelaker (1989) aged the population dentally using Moorrees et al. (1963a,b) before correlating diaphyseal length and chronological age. The age groups provided by Ubelaker (1989) span one year intervals assigned to the diaphyseal mean length and range of variation. The caveats of this method include the slower growth rates of the American Indian sample population as opposed to other European populations, which results in a relatively large standard deviation of up to two years. The sample sizes per age group vary dramatically, with only one or no individual representing the age categories of 12.5 years and above in particular. The reliability of the method is therefore better in the younger age categories with greater sample representation, at 2.5 years and below (Lewis 2002b, 34). Ghantus (1951) also provided mean diaphyseal lengths for the radius and ulna of modern American males and females aged below two years old. Greater sample sizes for older children were used in Gindhart (1973) who provided growth standards for diaphyseal length of the radius and tibia in modern American children aged one month up to 18 years old. Although age estimates using diaphyseal length are less accurate than dental ageing, it was deemed necessary to include the method in order to derive an age estimate for as many individuals as possible.

4.2.2.2.3. Skeletal maturation

Epiphyseal fusion times were taken from Scheuer and Black (2000) and Schaefer et al. (2009), which provide the age ranges at fusion of cranial, for example elements of the occipital bone, and post-cranial elements, for example fusion of the immature vertebral components or long bone epiphyses. Their data in turn was synthesised from radiographic assessments of the appearance and union of ossification centres. The postnatal sample is largely composed of modern longitudinal radiographic studies of European children or American children of European descent, originally compiled for clinical research. Participants have been examined radiographically throughout their growth period at a minimum of once a year, often up to three times annually during infancy (Scheuer and Black 2004, 10). These growth studies were initially undertaken to assess general health and growth across the population and between social classes and communities, and it may be argued that the repeated exposure to radiography itself caused an adverse effect on the participants' development (Tanner 1978). These records are however the primary source of information on skeletal maturation and fusion patterns and are not repeatable due to the awareness of health implication of continuous radiography (Scheuer and Black 2004, 10). Fusion data was recorded as the element and its stage of epiphyseal union (unfused, fusing/partially fused and complete fusion). The skeletal maturation of males and females undergoes different velocities, and averaged fusion times for both sexes were therefore used (Scheuer and Black 2004, 16).

4.2.2.3. Growth estimation

Long bone diaphyseal lengths of the femur, tibia, humerus, ulna and radius were plotted against dental age in one year age categories. Any individuals aged based on long bone lengths were excluded from this part of analysis. The precision of the measurements taken was calculated as the technical error of measurement (TEM) and reliability (R):

$$TEM = \sqrt{\frac{\sum D^2}{2N}}$$

D is the difference between two individual measurements of the same dimension, and *N* the total number of bones measured. The coefficient of reliability R is calculated as:

$$R = 1 - [(TEM^2)/(SD^2)]$$

where SD denotes the inter-subject variance for the study population and total measurement error. R ranges from 0 to 1 and reveals the percentage of variance between measurements due to measurement error (Ulijaszek 1998, 28). The technical error of measurement was calculated for a sub-sample of 27 femora from the Bath Gate, Cirencester archive. This collection was chosen due to ease of access and preservation. The TEM was calculated as 0.15 cm, and the coefficient of reliability was 0.97. This means that over 90% of the variance between the measurements is not due to measurement error, but other factors. It is expected that a similar TEM and coefficient of reliability is applicable for all other skeletal collections.

Growth profiles were then compared to those of Maresh (1955) based on radiographs of healthy modern children. The study includes measurements from 174 participants, both boys and girls. Since the data by Maresh (1955) is divided by sex, the average diaphyseal length at the 50th percentile for both boys and girls was used for comparison. From the age of ten years, Maresh (1955) provided long bone lengths including the epiphyses, whilst also providing diaphyseal lengths between the ages of ten and 12. To allow for comparison with the archaeological data encompassing diaphyseal lengths only, the percentage of the epiphyses on the long bone lengths for children aged ten to 12 years was calculated and then subtracted to give the diaphyseal length (Lewis 2007, 72).

The lower limb bones are more sensitive to stress, and the femorae and tibiae are one of the fastest growing bones of the human body (Eveleth and Tanner 1990, 35; Sciulli 1994). More long bone measurements of the femur (n=221) have been obtained as opposed to the tibia (n=206). Femoral measurements have therefore been plotted on scatterplots to compare growth in Romano-British and post-medieval non-adults from Christ Church Spitalfields, London. Femoral lengths were also plotted for comparison of growth in individuals with and without stress markers and pathological lesions.

4.2.3. Sex determination

The determination of sex in non-adult skeletons is problematic, and was not undertaken as part of the study as the focus is on urban and rural differences in child health rather than gender-based patterns. Although there is evidence for sexual dimorphism prior to the onset of puberty, the accuracy of current techniques based on metrics and morphology is insufficient. Most techniques yield between 70-85% accuracy (Saunders 2000, 138-139), bearing in mind that there is a 50% chance of guessing sex correctly. Sex was only determined in individuals when the acetabulum had commenced fusion, at around 11-15 years for females and 14-17 years for males (Scheuer and Black 2004, 338). The pubertal growth spurt and hormonal change will have initiated skeletal responses which allow sex determination from features of the skull and pelvis (Rogers 2009).

Sex determination of the skull involved scoring for sexual dimorphism of the nuchal crest, mastoid process, supraorbital margin, prominence of the glabella and mental eminence, as illustrated by Walker (1994) in Buikstra and Ubelaker (1994, 20), adapted from Acsadi and Nemeskeri (1970). It was recognised that the morphology of the non-adult cranium is more a product of growth rather than sex, which posed a caveat for this method (Lewis 2007, 51). Additionally, the error introduced by sexing of the skull is still as high as 20% (Walrath et al. 2004). It was therefore only referred to as a general indicator. Postcranial methods for sexing adolescents included sex determination of pelvic features. Sexing of the pelvis was based on the Phenice (1969) technique, assessing the presence of the ventral arc, subpubic concavity and medial aspect of the ischiopubic ramus, alongside the shape and depth of the greater sciatic notch (Buikstra and Ubelaker 1994, 18). Sex determination based on pelvic morphology is among the most accurate methods, with the ventral arc alone achieving accuracy of up to 96% (Sutherland and Suchey 1991). Rogers (1999) proposed sex determination in adolescents using four traits of the posterior distal humerus based on trochlear constriction, trochlear symmetry, olecranon fossa shape and depth, and angle of the medial epicondyle. The method is applicable to non-adult skeletons as soon as the distal humerus has fused, which may commence as soon as 11 years in females and 12 years in males (Scheuer and Black 2004, 274). Testing of the method by Rogers (2009) and Falys et al. (2005) on British and Portuguese documental archaeological samples yielded fluctuations in accuracy from 67% to 81%. The error associated with sexing of the distal humerus may be up to 33%. Lastly, the majority of individuals analysed in this study were skeletally too immature to provide either the distal end of the humerus, or a fused pelvis. Systematic sex determination was therefore not undertaken.

4.2.4. Dental and skeletal pathology

Previous work on Romano-British non-adults has highlighted the occurrence of metabolic disease, infections and biological stress, which were the focus of the current analysis. Any additional pathology, such as congenital and circulatory disorders were recorded according the standards and criteria set out in Ortner (2003). Fractures were also noted, as traumatic lesions can give valuable insight into lifestyles and occupations of people in the past (Ortner 2003, 136; Roberts and Manchester 2010, 84). Wherever possible, both the True Prevalence Rate (TPR) derived by the number of bones and teeth observed, and the Crude Prevalence Rate (CPR) that describes the percentage of pathology by individuals were presented.

Harris lines require systematic radiography, hence they will not be included in the standard recording procedures (Mays 1985). Notes on Harris lines were made if radiographs were in place or undertaken to assess another existing pathology.

Photographs of pathological lesions were taken throughout the recording phase to allow review at later stages. Radiographs were taken for selected individuals, to aid in dental ageing or for diagnostic purposes. However, curatorial measures had to be considered and did not always allow for radiography or removal of skeletons from archives.

4.2.4.1. <u>Dental pathology</u>

4.2.4.1.1. Dental disease

The dental inventory was taken following the shorthand in Schwartz (2007, 189). Teeth were individually recorded as present or absent. Periapical lesions were noted as an overarching term, as abscesses, cysts and granulomata are difficult to differentiate in archaeological materials (Brothwell 1981, 160; Hillson 1996, 287; Ogden 2008). Recording of dental pathology was limited to caries and periapical lesions only, as these constitute the main causes behind antemortem tooth loss (AMTL) (Brothwell 1981, 154). The presence or absence of carious lesions was recorded macroscopically in erupted teeth only. The total number of erupted teeth were noted per individual to allow for a discussion of true as opposed to crude prevalence rates. Erupted teeth present were divided into deciduous or permanent teeth, and anterior (incisors and canines) or posterior teeth (premolars and molars) (Buikstra and Ubelaker 1994, 47-48, 54; Hillson 1996, 6-9). Classifying loose teeth as (un)erupted involved an assessment of tooth development stages according to Moorrees et al. (1963a,b), and eruption patterns, wear and calculus to determine whether they were erupted and/or in occlusion (Buikstra and Ubelaker 1994). Caries was scored when the lesion perforated the tooth enamel (Hillson 1996, 269, 279), and prevalence rates were calculated based on the total of erupted teeth present for observation, rather than applying the caries correction factor (Lukacs 1995). When possible the location of the carious lesion was noted, whether it affected the root, cemento-enamel junction or crown. Location on the latter could be further distinguished as occlusal, buccal or interproximal affecting the crown on the mesial or distal aspect abutting a neighbouring tooth. Abscesses, cysts and granulomata were recorded only when they perforated the alveolar bone, as no systematic x-raying was undertaken to assess periapical lesions, and were reported per individual with erupted dentition present (Brothwell 1981, 156; Buikstra and Ubelaker 1994, 55; Ogden 2008). AMTL was recorded when the tooth socket exhibited remodelling, filling or healing of the margins, in order to avoid confusion with postmortem loss of teeth (Roberts and Manchester 2010, 74). Any additional anomalies such as impacted teeth, malformation of teeth or congenitally missing teeth were also noted (Hillson 1996, 109).

4.2.4.4.2. Dental enamel hypoplasia

Enamel hypoplasia generally manifests as contained, linear horizontal grooves encircling the tooth crown (Fig 4.37). These may also occur as clustered pits or cup-shaped indentations of reduced enamel thickness. Hypoplastic defects are most commonly observed in the central incisors of the maxilla and the canines of the mandible, although they may affect any tooth in the dentition (Saunders and Keenleyside 1999; King et al. 2005). Enamel hypoplasia was recorded by tooth affected and the type of lesion (pitted or grooved in permanent and deciduous teeth). Observations were purely based on macroscopic manifestations of enamel defects. Individuals without anterior dentition were excluded from scoring for presence or absence of enamel hypoplasia since hypoplastic defects occur more commonly on anterior teeth (Goodman and Armelagos 1985).

Figure 4.37. Dental enamel hypoplasia in two 10-13-year olds (from Wheeler 2012, 225)

Enamel defects may also occur in isolation due to infection or trauma, hence presence was only scored when the defect affected two or more teeth on opposite sides of the dentition (Goodman and Rose 1990). For the purposes of this research, it was not considered necessary to record the age at which the enamel defect occurred on the tooth. Without the use of destructive microscopic techniques, it is difficult to get a precise estimate of the time of occurrence. It is well documented that around 25% of the enamel layers that may contain an enamel defect are hidden inside the developing tooth crown. Additionally growth of the crown does not occur in a straightforward linear fashion, which hinders estimation of the chronological age at defect occurrence (Skinner and Anderson 1991; Hillson and Bond 1997; Malville 1997; Goodman and Song 1999; Reid and Dean 2000). Instead, the presence or absence of an enamel defect, and the affected tooth was recorded, with CPR and TPR rates reported in the results.

4.2.4.2. Non-specific infections: new bone formation, osteomyelitis and osteitis

Non-specific infections are traditionally described as sub-periosteal new bone formation, osteitis or non-sclerosis/non-suppurative osteomyelitis, and osteomyelitis (Figs. 4.38 and 4.39). Radiographic findings of sub-periosteal new bone deposits in infant long bones demonstrate that a periosteal reaction in this age group may arise from healthy rapid bone growth (Kwon et al. 2002; Rana et al. 2009; Shopfner 1966). This age group was therefore excluded when discussing new bone formation as an indicator of infections of non-specific origin. The precise aetiology of perisotitis, osteitis and osteomyelitis is impossible to determine on dry bone alone. Especially sub-periosteal new bone growth may also arise due to circulatory or haematological disorders, joint disease, trauma, skeletal dysplasia, or metabolic or neoplastic disease (Weston 2008). The location, distribution and state of healing of the sub-periosteal reaction was recorded, and evaluated in consideration of the presence and type of other pathological lesions in the skeleton as it may be part of wider systemic nutritional and infectious diseases (Lewis and Roberts 1997).

Periostitis, osteitis and osteomyelitis were recorded according to Ortner (2003, 181-215), noting the element, side and area affected, and providing a description of the macroscopic features of the lesion. Healing as opposed to active new bone deposits were distinguished based on Mensforth et al. (1978). Reactive woven new bone may signify a response to an inflammatory stimulus, whereas smoothing and remodelling of the lesion into dense lamellar bone is indicative of healing.

a, b,

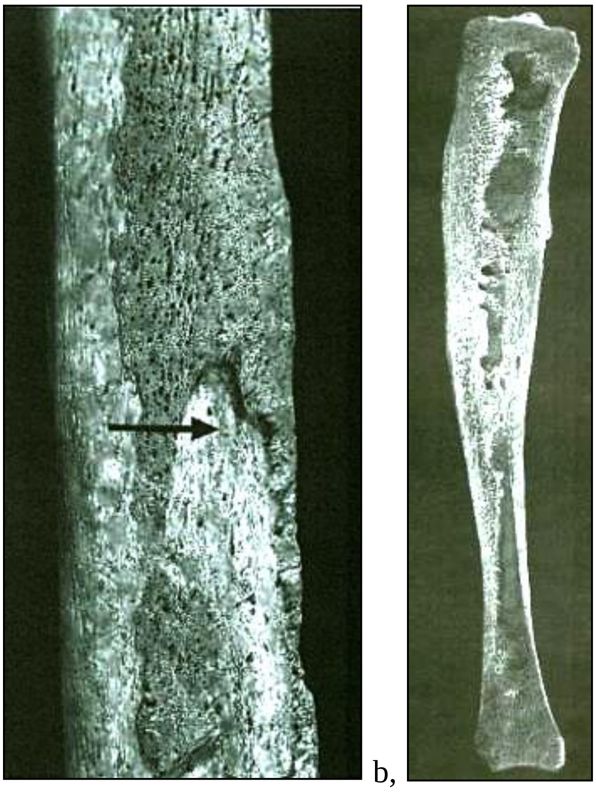


Figure 4.38. Sub-periosteal new bone formation and osteitis. a, Active periostitis on the left ulna of a 14-18-year old. The arrow indicates the underlying original cortex where some of the newly deposited reactive bone has broken away postmortem, from Ortner (2003, 210). b, Sagittal section through the left tibia of a 17-year old with chronic sclerosing osteomyelitis. Lytic cavities and medullary sclerosis. Note the absence of sequestra and cloacae (from Ortner 2003, 190).

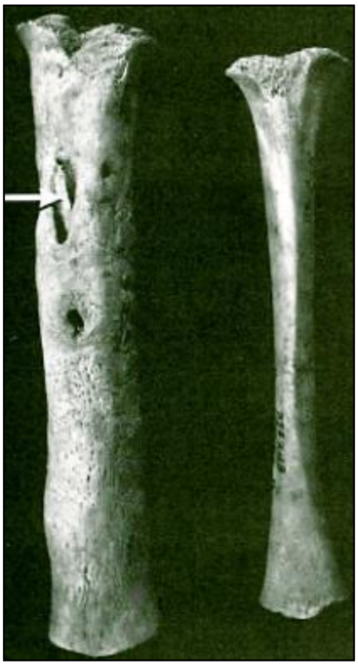
a,  b, 

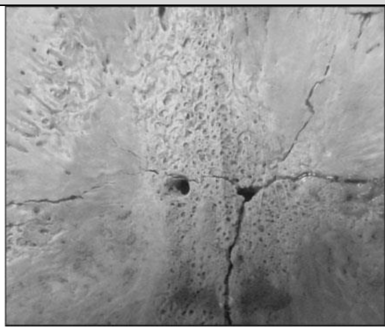
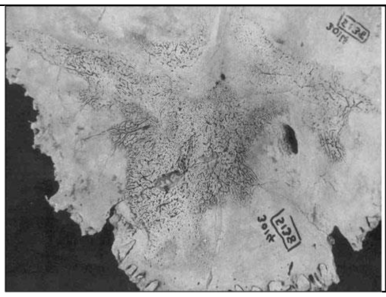
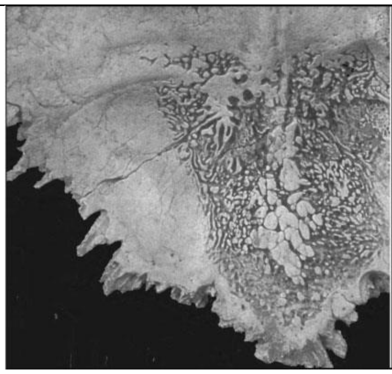
Figure 4.39. Osteomyelitis. a, Tibiae of a 9-year old, anterior. Left: left tibia with osteomyelitis. Note the involucrum with cloacae and the exposed sequestrum (arrow). Right: normal right tibia of the same individual. b, Radiograph of tibiae, mediolateral. Left: arrows indicate the necrotic original cortex (sequestrum), enclosed by involucrum. Note the presence of Harris lines in the normal tibia on the right (from Ortner 2003, 201-202)

4.2.4.3. Endocranial lesions

Endocranial lesions describe new bone formation and lytic foci on the inner table of the skull. These may either be found around meningeal vessels or as isolated islands of new bone. Impressions may extend into the inner lamina of the endocranial surface or more extreme marrow extension of the diploë can be observed, resulting in 'hair-on-end' appearance. These defects are most commonly located on the occipital bone, but may also occur on the parietal or frontal bones (Lewis 2004). The location and distribution of these lesions is vital in distinguishing normal bone growth in young children from a pathological proliferation. If the lesion is contained to the occipital bone, particularly around the cruciate eminence, it may be a manifestation of regular healthy bone growth in infants. When the endocranial lesion was porous in nature and contained to the cruciate eminence in infants up to six months old, it was still recorded but not interpreted as indicative of an inflammatory response. If, however, the proliferative growth is more widespread and involves the parietals or frontal bones, it is likely to be pathological. Lesions were recorded according to Lewis' (2004) scoring criteria (Table 4.4).

Impressions of vessels formed in the new bone deposits are indicative of healing. 'Hair-on-end' lesions with an increasingly frosted appearance are also healing as the bony projections undergo remodelling (Lewis 2004; 2007, 142).

Table 4.4. Scoring system for diagnosing endocranial lesions

Stage	Description of osseous change	Photograph
Type 1	Pitted lesions with increased porosity, often on the occipital bone.	 Occipital endocranial surface of a full-term infant with type 1 lesions, from Lewis (2004, 89)
Type 2	Deposits of fibrous or immature new bone, often white or grey in appearance.	 Occipital endocranial surface of a child's skull with type 2 lesions, from Lewis (2004, 89)
Type 3	Capillary lesions with vascular impressions, no evidence of new bone formation.	 Occipital endocranial surface of a child's skull with type 3 lesions, from Lewis (2004, 90)
Type 4	'Hair-on-end' formation, lesions as an extension of the diploë.	 Occipital endocranial surface of a child's skull with type 4 lesions, from Lewis (2004, 90)

From Lewis (2004)

4.2.4.4. Specific infections: tuberculosis

Tuberculosis is a respiratory infection caused by *Mycobacterium tuberculosis* and *Mycobacterium bovis*. In children, tuberculosis leaves a series of lesions throughout the skeleton (Fig. 4.40). A strong diagnosis for probable tuberculosis could only be made when spinal spondylitis (Pott's Disease) was evident (Table 4.5). Possible and probable cases of tuberculosis were evaluated assessed based on criteria outlined in the palaeopathological literature (Pfeiffer 1984; 1991; Santos and Roberts 2001; Ortner 2003, 230-253; Roberts and Buikstra 2003; Lewis 2011). Additionally, description of skeletal changes and radiographically observable lesions in the clinical literature were consulted (Resnick 2002, 2527-2539; Resnick and Kransdorf 2005, 758-763).

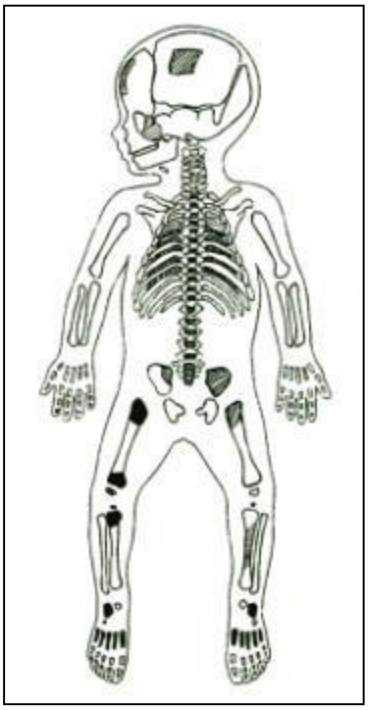


Figure 4.40. Distribution of skeletal lesions in childhood tuberculosis, with the most frequently affected areas in black and less frequently affected areas hatched (from Lewis 2007, 150)

Table 4.5. Diagnostic criteria for non-adult tuberculosis

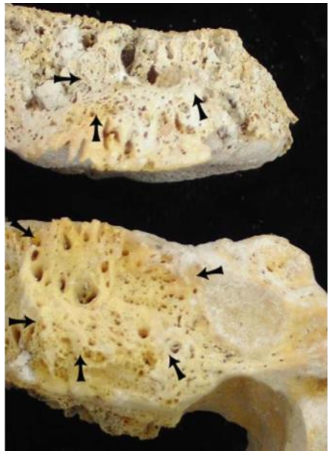
Element	Description of osseous change	Photograph/radiograph
Spine	- destruction of bone and minimal new bone formation - tuberculous spondylitis/Pott's disease as lytic lesions in the spine: mainly contained to thoracic and lumbar vertebrae, collapse may eventually lead to kyphosis - Pott's disease as pathognomonic - involvement of L1 most common, frequency of vertebral lesions decreases as one moves up or down the spine - tuberculous lesions affect vertebral body, either through an initial focus in the haematopoietic marrow or a paravertebral or psoas abscess - infectious foci mainly contained to the anterior and lateral aspects - erosion of affected vertebral bodies commences from the inferior or superior margin, involving one to four vertebrae at a time	a,  b,  a, lower thoracic vertebral bodies of an older child, localised depressions on the cortex and sclerotic new bone formation, from Lewis (2011, 17) b, left lateral view of the spine of a 9-year old with Pott's disease, destruction and collapse of L12 with angulation and kyphosis, from Roberts and Manchester (2010, 188)

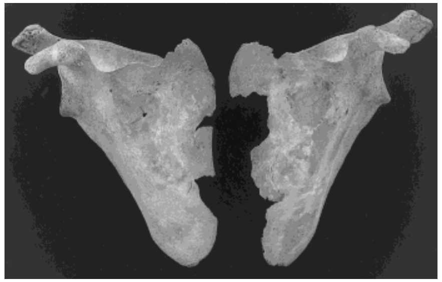
Table 4.5. continued

Ribs	- three types of rib lesions: plaque (layers of dense periosteal new bone), expansion (porous, cortical new bone may blend into existing bone shape), resorption (erosive lesions on head and neck, corresponding to lytic resorption of affected thoracic vertebral bodies) - lytic lesions apparent on shaft at low rate and random distribution - active periostitis on the visceral rib surface (indicative of a respiratory disorder and not pathognomonic of tuberculosis), new bone formation most evident on ribs 4 to 6, not affecting 1^{st}, 11^{th}, 12^{th} ribs, new bone largely apparent towards vertebral end, periosteal reaction as an addition to the periosteal layer/extension of periosteum - proliferation often bilateral, but singular foci of lytic lesions	 Visceral surface of left eighth and ninth ribs of a 17-year old with tuberculosis, lytic lesion on the inferior margin of the eighth rib, from Ortner (2003, 233)  Active new bone formation on the visceral aspect of left ribs, from Santos and Roberts (2001, 43)

Table 4.5. continued

Hands and feet	- tuberculous dactylitis: swollen and puffy appearance, involving entire diaphysis with resorption of cortex - mainly reported in children below ten years - more likely in hands than feet and fingers than metacarpals - destruction of growth plate with shortening of the digit is apparent - differential diagnosis: congenital syphilis and osteomyelitis with comparable lesions - osteomyelitis as singular lesion - evidence for treponemal infection does not occur in Europe until a millennium later	 Dactylitis in the metacarpals of a 3-5-year old, from Ortner (2003, 204)  Right metacarpal of an older child, from Lewis (2011, 18)

Table 4.5. continued

Skull	- bony changes involving the skull are rare, mostly found in young children only - widespread periostitis - lytic lesions as singular round foci on cranial vault - active resorption, no evidence for remodelling or healing - extreme cases with perforation of inner and outer tables - osteomyelitis of the mandible	 Mandible of a 3-year old with tuberculous osteomyelitis, from Lewis (2011, 18)
Post-cranial skeleton	- widespread periostitis - osteomyelitis - epiphyses and metaphyses prone to infection, common involvement of hips, knees, ankles - cystic lesions vary in size, may be symmetrical with no evidence of sclerosis and remain localised rather than extending across the epiphysis and into the joint - lytic skeletal lesions exhibit necrosis and reduced new bone formation with signs of osteoporosis	 Widespread new bone deposits on left upper limb of older child, from Lewis (2011, 18)  Non-adult scapulae with extensive new bone formation, from Santos and Roberts (2001, 45)

From Pfeiffer (1984; 1991) Santos and Roberts (2001), Resnick (2002, 2527-2539); Ortner (2003, 230-253), Roberts and Buikstra (2003), Resnick and Kransdorf (2005, 758-763) and Lewis (2011)

4.2.4.5. Cribra orbitalia and porotic hyperostosis

Cribra orbitalia and porotic hyperostosis (Fig. 4.41) were recorded according to the scheme devised by Stuart-Macadam (1991). Although scored using the same criteria, their presence was recorded separately to take account of their potentially different aetiologies (Wiggins 1996).

Figure 4.41. Prominent porotic hyperostosis in a 3-year old. Note the extensive pitted and perforated ectocranial lesions (from Walker et al. 2009, 110)

The scoring system is graded from 0 to 5, where 0 denotes normal bone with no signs of hyperostosis and 5 refers to the most severe lesions. The stages of 0-5 were described by Stuart-Macadam (1991, 109) as follows, and are illustrated in Figure 4.42:

0=normal bone surface	3=small and large isolated foramina
1=capillary-like impressions on the bone	4=foramina link into a trabecular structure
2=scattered fine foramina	5=outgrowth in trabecular form on outer table surface

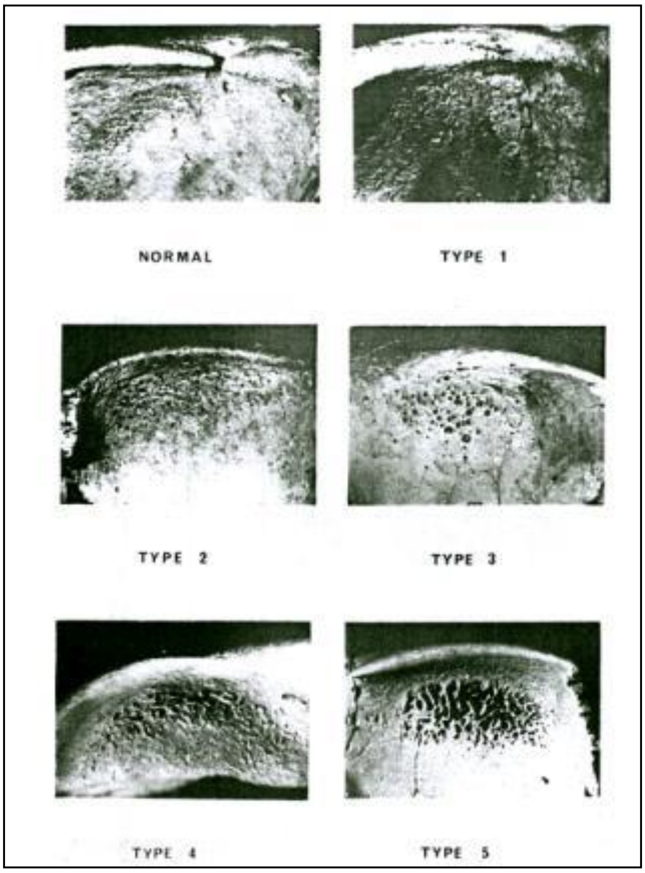


Figure 4.42. Five grades of cribra orbitalia after Stuart-Macadam (1991, 109)

For both cribra orbitalia and porotic hyperostosis, expressions below Grade 3 were discounted to prevent over-recording of lesions, and unilateral or bilateral occurrence was noted. Lesions were also assessed to determine healing as opposed to active stages. This approach aids in providing an holistic picture of the stress and disease suffered by an individual, especially when considered in conjunction with other pathologies. Remodelled or healed lesions show a smooth lamellar texture, with evidence of filling of the microporosity. Unremodelled or active lesions exhibit sharp and defined edges to the exposed trabecular structure with marked microporosity (Mensforth et al. 1978).

4.2.4.6. Metabolic disease

4.2.4.6.1. Vitamin D deficiency (rickets and osteomalacia)

The methods and diagnostic pathological features outlined in Ortner and Mays (1998), Ortner (2003, 394-400) and Mays et al. (2006) were followed for identifying skeletal manifestations of probable rickets and osteomalacia in non-adults. Diagnosis was based on the criteria listed in Table 4.6, with evaluation of the element, side and area affected, and the severity and extent of the lesion. Changes at the metaphysis and growth plate which are commonly observed in rachitic non-adults are displayed in Figure 4.43. Active cases of rickets were distinguished from healed rickets as those showing porosity of the cortical bone and metaphyseal plate as a result of unmineralised osteoid. Recovery from vitamin D deficiency initiates smoothing of the porous lesions due to increased mineralisation and filling of the holes (Ortner and Mays 1998). Healing of concave bending deformities may also show sub-periosteal new bone deposits (Mays et al. 2006). Cupping and swelling of the metaphyses can be evident in healed cases (Brickley and Ives 2008, 91). Pathological fractures, alongside Looser's zones which are pseudofractures manifesting as lines of unmineralised osteoid at sites of skeletal stress, may be present and identified radiographically (Pettifor and Daniels 1997; Pettifor 2003).

Co-morbidity of metabolic disease is likely, and lesions indicative of vitamin D deficiency can be accompanied by or indistinguishable from vitamin C deficiency. Anaemic responses including cribra orbitalia and porotic hyperostosis can also occur simultaneously with chronic vitamin deficiencies (Stuart-Macadam 1989b; Pettifor 2003; Brickley and Ives 2008, 113-114).

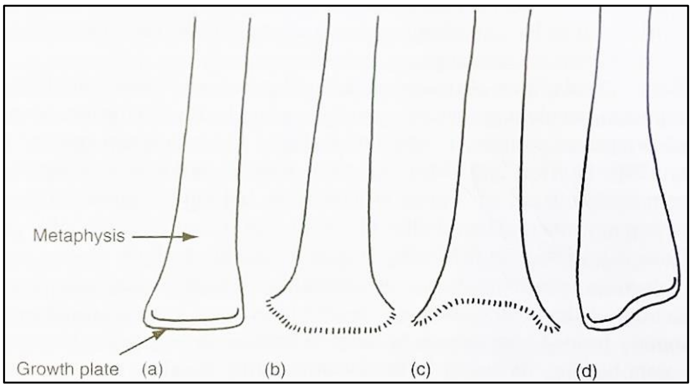


Figure 4.43. Pathological changes at the growth plate and metaphysis of a non-adult radius in vitamin D deficiency; a, normal outline; b, growth plate in active rickets with increased porosity; c, increased porosity and cupping in rickets; d, angulation of the growth plate and swollen metaphysis in severe rickets (from Brickley and Ives 2008, 91).

Table 4.6. Diagnostic criteria for vitamin D deficiency in non-adult skeletons

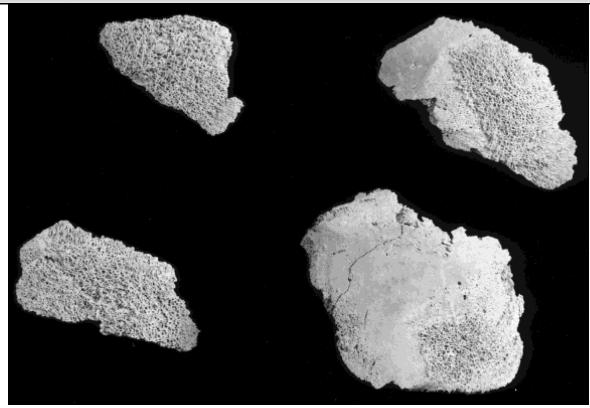
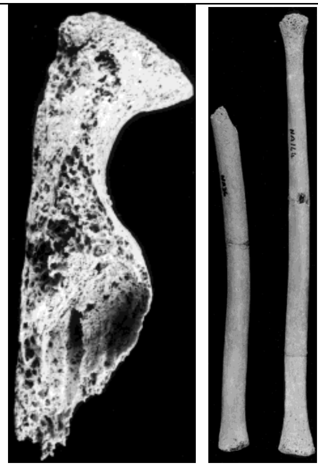
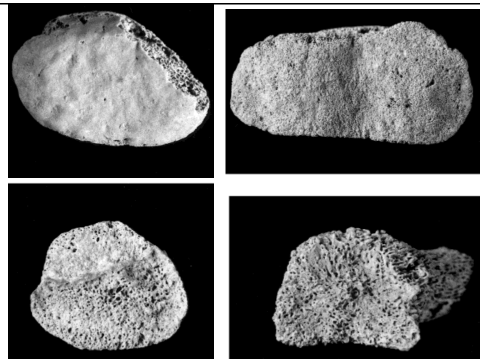
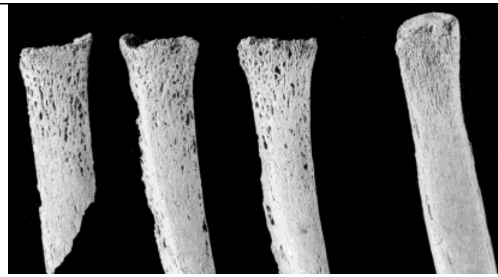
Element	Description of osseous change	Photograph
Cranial vault, Orbital roof	The skull may develop craniotabes, resulting in asymmetrical deformity of the skull. Porosity and pitting is evident on the ectocranial surface and orbital roofs. Subperiosteal new bone on the ectocranial surface results in remodelling of the outer table, resembling anaemic bony changes. Differential diagnosis is required based on other rachitic changes in the postcranial skeleton.	 Marked porosity on endocranial aspect of infant cranial fragments, from Ortner and Mays (1998, 47)
Mandible, long bones, ilium, scapula	Bowing refers to the smooth and gradual curve observed in bending deformities due to rickets. Observing bowing of the long bones in infants may be problematic. These children did not walk, however bending due to crawling or lifting the torso when rolling over may be apparent in the upper limbs.	 Superior view of right mandibular ramus and right fibulae of rachitic (on the left) and healthy infant, from Ortner and Mays 1998, 49, 50)

Table 4.6. continued

Long bones	Apart from a bowed appearance, long bones in rachitic non-adults may also show thickening, somewhat reminiscent of swelling. The swollen appearance may be particularly evident around the metaphyseal plates.		On the left: left radius and ulna of a rachitic infant of three months. Normal radius and ulna on the right for comparison, from Ortner and Mays (1998, 49)
Metaphyseal plates	The cortex of the metaphyses in the long bones of the arms and legs may show roughening and increased porosity.		Stages of porosity and roughening of epiphyseal plates, from Ortner and Mays (1998, 54)
Ribs	Similar to the flaring, thickening and porosity seen in the metaphyseal ends of long bones, ribs may appear flared, thickened and porous at the costo-chondral end.		Sternal rib fragments, with rib of a healthy child on the far right, from Ortner and Mays (1998, 53)

From Ortner and Mays (1998), Ortner (2003, 394-400) and Mays et al. (2006)

4.2.4.6.2. Vitamin C deficiency (scurvy)

Skeletal manifestations of infantile scurvy are mainly contained to the cranium as porous and hypertrophic lesions (Brickley and Ives 2008, 56-61). Sub-periosteal bleeding on the orbital roof commonly occurring in scurvy, can also lead to ossified deposits of vascularised woven bone (Sloan et al. 1999). Scorbutic lesions are mainly bilateral and affect the greater wings of the sphenoid and posterior aspects of the maxillae (Brickley and Ives 2006). Parrot's swelling is also characteristic, an enlarged cranial boss exhibited on the parietals (Fig. 4.44).

a,  b, 

Figure 4.44. Probable cranial and post-cranial scorbutic lesions. a, infant skull with extensive ectocranial porosity and exaggerated frontal and parietal boss (from Ortner and Ericksen 1997, 214); b, infant humerii and femorae with enlarged zones of porosity at metaphyseal ends (Ortner et al. 2001, 348)

The woven bone deposited in response to the periosteal inflammation may remodel into lamellar bone towards the more chronic spectrum of the deficiency (Ortner and Ericksen 1997). A diagnosis of probable scurvy was made according to the criteria provided by Ortner and Ericksen (1997), Ortner et al. (1999) and (2001), and Brickley and Ives (2006) in Table 4.7. This method emphasises cranial and scapular involvement, noting the element, side and area affected, and severity and extent of the lesions. Ortner et al. (2001) also proposed to take abnormally enlarged areas of porosity in metaphyseal ends of long bones into account when cranial changes are evident. These may be pathological in origin if they extend beyond 10mm from the growing metaphysis which is a product of healthy regular growth (Fig. 4.44). Scurvy in non-adults, and especially infants, is notoriously difficult to diagnose due to widespread new bone formation and associated porosity as a result of healthy growth. A useful description of normal versus abnormal vascularity was offered by Ortner et al. (1999; 2001). Abnormal porosity is localised, and penetrates a compact bone surface by leaving fine holes which are normally below 1mm in diameter and recognisable to the naked eye. These lesions may also be accompanied by new bone formation. The normal porosity often seen in non-adult bone is however less densely vascularised with holes that may have a greater diameter. The distribution of sites of abnormal porosity throughout the skeleton is paramount in differentiating pathological as opposed to growth-related vascularity. Zuckerman et al. (2014) proposed that scorbutic ectocranial porous lesions correlate with an increase in cranial vault thickness, which is a useful indicator for scorbutic as opposed to healthy new bone deposits. Healed cases of scurvy were differentiated based on the Mensforth et al. (1978) criteria. Healed lesions exhibit smoothing or filling of the porosity, whereas active lesions are characterised by sharp edges of the microporosity.

Table 4.7. Diagnostic criteria for vitamin C deficiency in non-adult skeletons

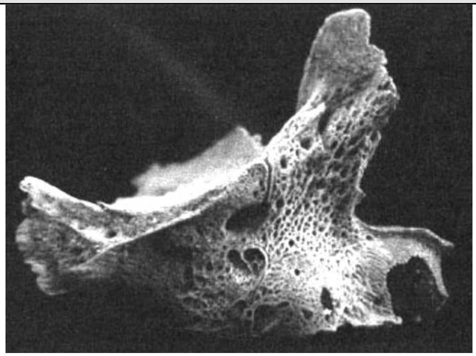
Element	Description of osseous change	Photograph	
Maxilla	Pitted and porous new bone deposits may extend beyond the alveolar process and stretch towards the frontal process on the ectocranial surface.		Lateral view of right infant maxilla, from Brickley and Ives (2006, 165)
Hard palate	The hard palate naturally exhibits a level of porosity around the alveolar process of erupting teeth in healthy individuals. If this porosity is increasingly extreme and extends beyond the alveolar process it is viewed as indicative of scurvy.		Inferior view of right hard palate of infant maxilla, from Brickley and Ives (2006, 166)

Table 4.7. continued

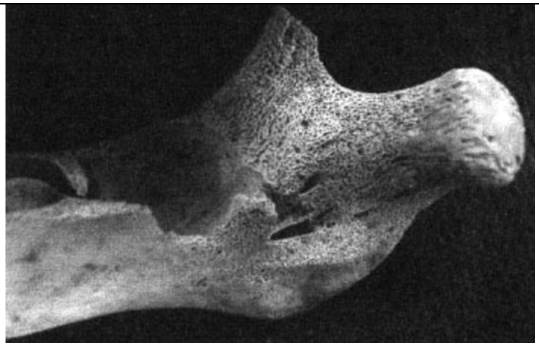
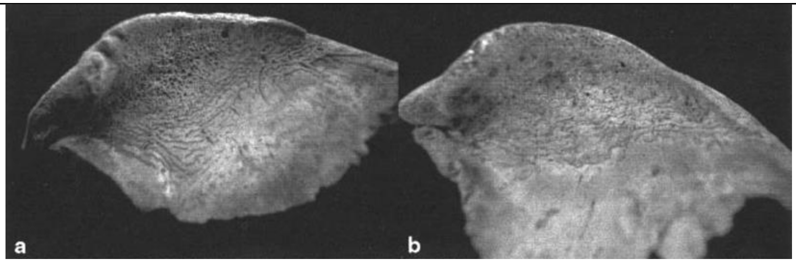
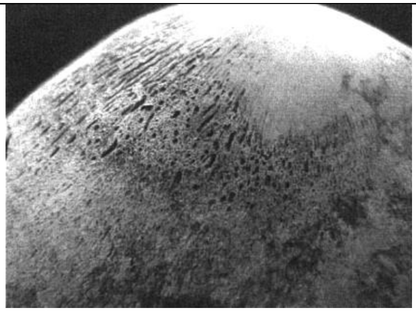
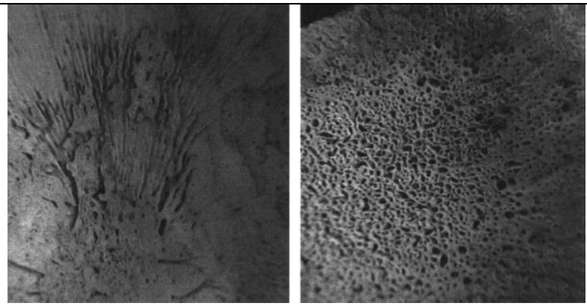
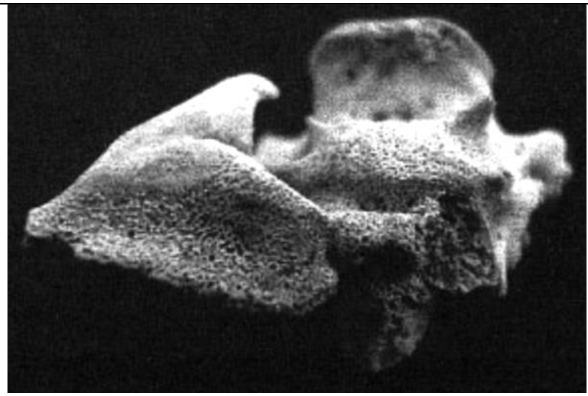
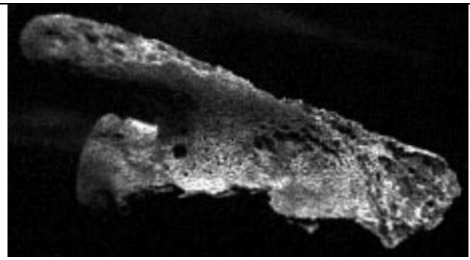
Mandible	Porosity may affect the coronoid process and spread around the mandibular foramen. Porous areas are localised and do not involve the alveolar process when attributed to scurvy.	 Medial view of right infant mandible, from Brickley and Ives (2006, 166)
Orbits	The orbital roof may exhibit lesions similar to those seen in cribra orbitalia due to increased vascularisation of the cortex. Cribra orbitalia can be differentiated from scorbutic lesions in the orbits. The latter being characterised by abnormal porosity and newly deposited bone laid down in discrete layers rather than hypertrophic marrow expansion.	 Inferior view of infant orbital roofs; a, displays abnormal vascular bone deposits; b, shows the normal range of porosity of healthy bone growth, from Brickley and Ives (2006, 167)
Parietals	The ectocranial surface may be increasingly porous with extensive vascularisation. The pitting and perforations are irregular in size and pattern. The porosity may be accompanied by an increase in vault thickness.	 Infant ectocranial parietal surface, from Brickley and Ives (2006, 168)

Table 4.7. continued

Occipital	The endocranial surface of the occipital may exhibit porosity penetrating the cortex. Localised increased vascularity is apparent with coarsening of the cortical bone.		Endocranial occipital surface of two infants, from Brickley and Ives (2006, 169)
Sphenoid	It is mainly the greater wings that show porous new bone deposition but scorbutic lesions can also affect the lesser wings and body of the sphenoid.		Infant sphenoid, from Brickley and Ives (2006, 169)
Scapula	Both the supra- and infraspinous fossae may display abnormal porosity, similar in appearance to the scorbutic lesions observed in the cranium.		Superior view of right infant scapula, from Brickley and Ives (2006, 170)

From Ortner and Erickson (1997) Ortner et al. (1999; 2001) and Brickley and Ives (2006)

4.2.4.6.3. Thalassaemia

Skeletal evidence for *thalassaemia major* and *intermedia* in Romano-British non-adult skeletons was discussed by Lewis (2012), warranting awareness of its diagnostic criteria to evaluate the prevalence of this genetic anaemia in other skeletal collections from varying Romano-British settlement types. The method followed in this study is mainly based on Lewis' (2012) assessment criteria for thalassaemia in the Poundbury Camp non-adults. Reference was also taken from Ortner's (2003, 364-366) discussion of bony changes indicative of thalassaemia, Tyler et al.'s (2006) radiological study of thalassaemic skeletal changes and Lagia et al.'s (2007) case study of a 14 year old girl with thalassaemia from a modern reference collection, see Table 4.8.

4.2.4.6.4. Malaria

Porotic hyperostosis and cribra orbitalia may indicate an anaemic response as a result of iron-deficiency anaemia, thalassaemia or sickle-cell anaemia (Caffey 1937; Hershkovitz et al. 1991; Hershkovitz et al. 1997; Ortner 2003, 364; O'Donnell et al. 2009). The latter two conditions are an adaptive response to malaria and increase resistance to the virus (O'Donnell et al. 2009). Malaria is generally interpreted as only yielding non-specific bony changes (Gowland and Western 2013). It is mainly the presence of genetic anaemias in endemic populations that may hint at malaria being the driving force behind altered red blood cell production (Mitchell 2003; Roberts and Manchester 2010, 234; Ustundag 2011). Recent research by Smith-Guzmán (2015) attested that porous lesions on the cranium, vertebral column and the necks of humerii and femora were more frequently seen in a documented Ugandan population where malaria is endemic. Compared to a modern poplation from a malaria-free area, periostitis also seemed to prevail in the endemic study sample. Although non-specific, these skeletal changes add to our ability to recognise malaria in the osteological record.

Table 4.8. Diagnostic criteria for non-adult thalassaemia

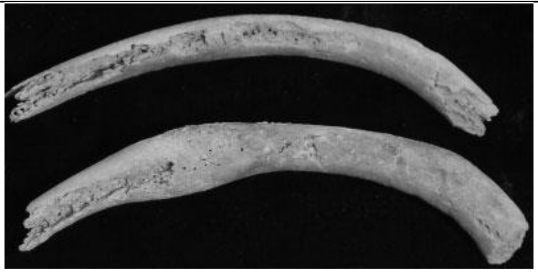
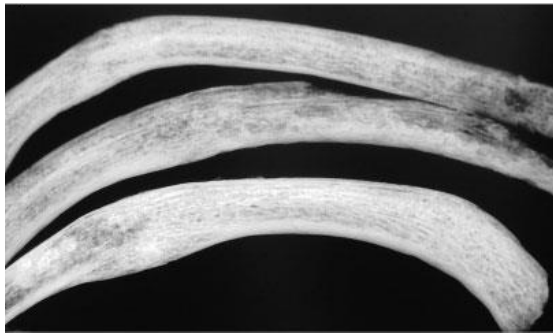
Element	Description of osseous change	Photograph/radiograph
Ribs: costal osteoma	- benign neoplastic lesion mostly formed of lamellar bone - swollen aspects of hyper-marrow bone on the original cortex of the rib - radio-opaque appearance - gross macroscopic examination: element affected, side, position and extent of the osteoma - care must be taken when diagnosing and interpreting these osteomas without the use of radiographs, as they emerge similar to fracture calluses - x-rays taken whenever possible	 ribs of an infant with localised mass on cortex, visceral aspect, from Lewis (2012, 690)  radiographs of the same individual as above, radio-opaque appearance of the localised mass, laid on top of the original cortex, from Lewis (2012, 690)

Table 4.8. continued

Ribs: rib-within-a-rib	- radiographs: radio-opaque band within the affected rib - longitudinal marrow expansion within the cortex - posterior aspects of the ribs expand posteriorly which may correspond with paraspinal extra-medullary haematopoiesis - gross macroscopic examination: rib-within-a-rib appearance emerges as pitting and thickening of the ribs with hypertrophic aspects and costal osteomas - x-rays taken whenever possible	 ribs of an infant with extensive pitting and localised thickening (arrows), from Lewis (2012, 689)  radiograph: cortical osteomas as localised radio-opaque lesions, rib-within-a-rib observed as radiolucent posterior margins displaying hair-on-end, from Lewis (2012, 689)

Table 4.8. continued

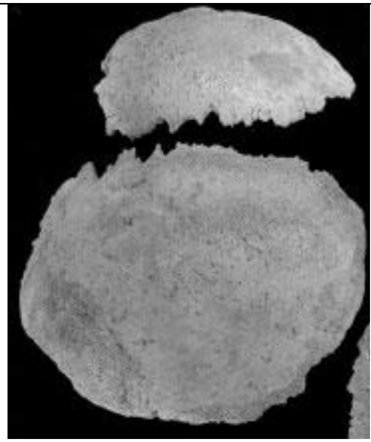
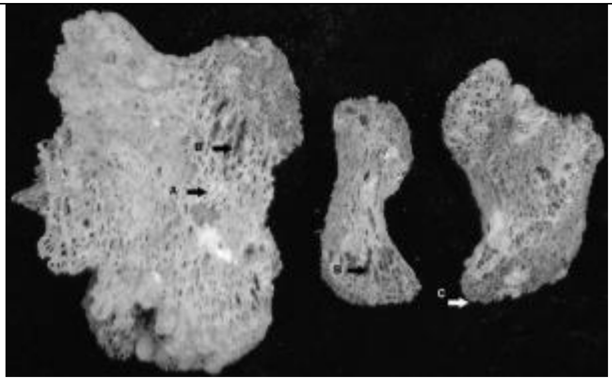
Skull	- porotic hyperostosis - cribra orbitalia - generalised periosteal and/or trabecular thickening	 thickened cranial vault fragments of an infant with skeletal changes indicative of thalassaemia, from Lewis (2012, 689)
Long bones	- thickening and pitting - flaring of the metaphyses in isolated cases but remains a predominantly rachitic lesion - lytic lesions with areas of necrosis may be found on metaphyses	 infant postcrania: thickening of the long bones and flaring of metaphyses, from Lewis (2012, 690)

Table 4.8. continued

General skeleton	- osteopenia: thinned cortex and meagre cancellous bone with reinforced vertical trabeculae - widespread pitting - cortical thinning - general 'wasting' (Lewis 2012) - criteria necessary for a differential diagnosis of anaemic conditions	 Osteopenia: ischium and pubis with (A) thinning and porosity of the cortex and (B) a reinforced thickened trabecular structure (C) denotes postmortem damage for comparative means, from Lewis (2010, 412)

From Ortner (2003, 364-366), Tyler et al. (2006), Lagia et al. (2007) and Lewis (2012)

4.2.5. The burial archaeology

In order to provide a holistic approach to the study of health in Romano-British non-adults, a brief overview of palaeopathology in relation to the burial archaeology was sought. It was considered of interest to evaluate patterns of stress and disease according to burial alignment, in unusual burials outside of the main cemetery area, by body position within the grave and in inhumations with and without grave goods. True and crude prevalence rates of cribra orbitalia, enamel hypoplasia, non-specific infection, metabolic disease and dental disease were tested between different burial groups.

4.2.6. Statistical analysis

A minimum confidence limit of 99.9% was adhered to for all tests, and results at the 99.5% level were also considered. Non-parametric statistical tests include Pearson's Chi-square test to inform on significant differences in frequencies of skeletal or dental lesions between site types and age groups (Shennan 1997, 105-111):

$$X^2 = \Sigma \frac{(observed\ frequencies - expected\ frequencies)^2}{expected\ frequencies}$$

Yate's correction for continuity was used to correct for small sample sizes, by subtracting 0.5 from positive values for (*observed frequencies – expected frequencies*), and adding 0.5 for negative values for (*observed frequencies – expected frequencies*) (VanPool and Leonard 2011, 252-253).

For comparison of long bone lengths (growth curves between two samples) Kolmogorov-Smirnov Z was selected to test for differences in the distribution of two sets of observations in long bone measurements (Shennan 1997, 57-60). This test is similar to the Mann-Whitney test in assessing whether two groups have been drawn from the same cohort, but is better suited for smaller sample sizes of under 25 individuals per group (Field 2013, 877):

KS = $1.95\sqrt{\frac{n_1+n_2}{n_1 n_2}}$ for a minimum confidence level of 0.05 (Shennan 1997, 60).

The Kruskal-Wallis non-parametric one-way ANOVA was selected as a ranking-based test for comparing three distributions (femoral growth between the three site types) (Sheskin 2003, 757; Field 2013, 236-237):

$$H = \frac{12}{N\,(N+1)} \sum_{i=1}^{k} \frac{R_i^2}{n_i} - 3\,(N+1)$$

Yule's Q was calculated as a measure of association between two variables, quantifying the relationship of two stress indicators, dental or skeletal lesions with one another (Shennan 1997, 116-117). Q is based on a 2×2 table and calculated using the following equation:

$$Q = \frac{ad - bc}{ad + bc}$$

The paper recording form used by the author for the primary study sample is attached in Appendix I. Microsoft Access 2013 was used as the software package to store the palaeopathological data of the primary study sample, the combined study sample, and dental data of the primary study sample. Microsoft Access 2013 was also used for analysing frequency distributions. The key used for abbreviations in the three databases is summarised in Appendix II. Appendix III contains a list of the dental development stages used after Moorrees et al. (1963a,b) and Smith (1991). Chi-square tests were performed using Microsoft Excel 2013. For the Kolmogorov-Smirnov Z and Kruskal-Wallis one-way ANOVA, SPSS21 was selected as the statistics package. The SPSS output for these tests is attached in Appendices IV and V.

CHAPTER 5. RESULTS I – THE PALAEOPATHOLOGY

5.1. THE STUDY SAMPLES

The results of the statistical analyses are presented below. In order to provide a comprehensive review of non-adult health in Roman Britain, the results for 1643 individuals from 27 sites are presented first. The data was derived from both primary data collection (N=953 from 15 sites) and secondary sources (N=690 individuals from 13 sites using published and unpublished skeletal reports). Due to the skeletal data available, patterns in the distribution of palaeopathology in the combined study sample were analysed using crude prevalence rates (CPR) only. More in-depth results are presented following the overview, using the primary study sample which only contains palaeopathological and age-at-death data recorded by the author. The more detailed data collection for the primary study sample allowed for true prevalence rates (TPR) to be explored.

The limitations of the combined study sample are discussed in chapter 7. One of the caveats of using a combined study sample is that methods for skeletal and palaeopathological recording differ between site reports and the data collected by the author. Errors associated with skeletal and dental ageing were controlled for by assigning every individual to a standardised age category. These were referred to when presenting age-based patterns in the distribution of pathologies. The use of age groups was intended to minimise the bias introduced by the error ranges in skeletal and dental ageing methods. It also help to consolidate the methodological discrepancies in non-adult ageing between the sample analysed by the author and those extracted from the literature. For presenting growth data individual mean ages in .25 increments were used, based on all skeletal and dental age indicators available. Mean ages rather than age groups have to be used in order to construct meaningful graphs based on long bone length attainment by age, and to allow for the meaningful comparison of growth curves. A diagnosis for pathology was only made when 75% of the respective elements were present, for example 75% of the orbital roof for cribra orbitalia, or 75% of the axial and appendicular skeleton for rickets. This approach was sought to minimise bias in diagnosing pathologies when individuals were insufficiently preserved.

5.2. THE COMBINED STUDY SAMPLE

This study sample comprises of the primary study sample that the author has collated, together with the secondary data from the (un)published literature. A total of 1643 non-adult individuals are included in the combined study sample, with a bias towards non-adults from major urban cemeteries. In total 886 (53.9%) non-adults stem from eight major urban cemeteries, 440 (26.8%) from eight minor urban burial grounds, and 317 (19.3%) individuals have been included from 11 rural sites.

5.2.1. Age-at-death

The demographic profile of the 1643 non-adults available for study is given in Table 5.1. Individuals that were too fragmentary or incomplete for ageing (6.8%, n=112), were assigned to the 'non-adult' age category. For the total sample of 1643 individuals, mortality peaked in the infant age category (23.9%, n=392). The lowest mortality rate was recorded in preterm babies (3.5%, n=21). Mortality declined immediately after infancy with 11.4% (n=188) in 1.1-2.5-year olds, with a rise in 2.6-6.5-year olds (15.4%, n=253). Mortality then steadily declined further with the lowest relative frequency at 4.9% (n=80) for the 14.6-17.0 year age group. These patterns can be further explored when examining differences in age-at-death between the site types (Fig. 5.1).

Table 5.1. Distribution of ages-at-death in the combined study sample

Age	**Major urban**		**Minor urban**		**Rural**		**Total**	
	n	*%*	*n*	*%*	*n*	*%*	***N***	***%***
< 37 wks	21	2.4	18	4.1	18	5.7	**57**	**3.5**
38-40 wks	122	13.8	66	15.0	77	24.3	**265**	**16.1**
0-1.0	170	19.2	145	32.9	77	24.3	**392**	**23.9**
1.1-2.5	97	10.9	57	12.9	34	10.7	**188**	**11.4**
2.6-6.5	140	15.8	70	15.9	43	13.6	**253**	**15.4**
6.6-10.5	107	12.1	31	7.1	18	5.7	**156**	**9.5**
10.6-14.5	86	9.7	31	7.1	23	7.3	**140**	**8.5**
14.6-17.0	49	5.5	13	2.9	18	5.7	**80**	**4.9**
Non-adult	94	10.6	9	2.1	9	2.8	**112**	**6.8**
Total	**886**		**440**		**317**		**1643**	

% of the cohort by site type

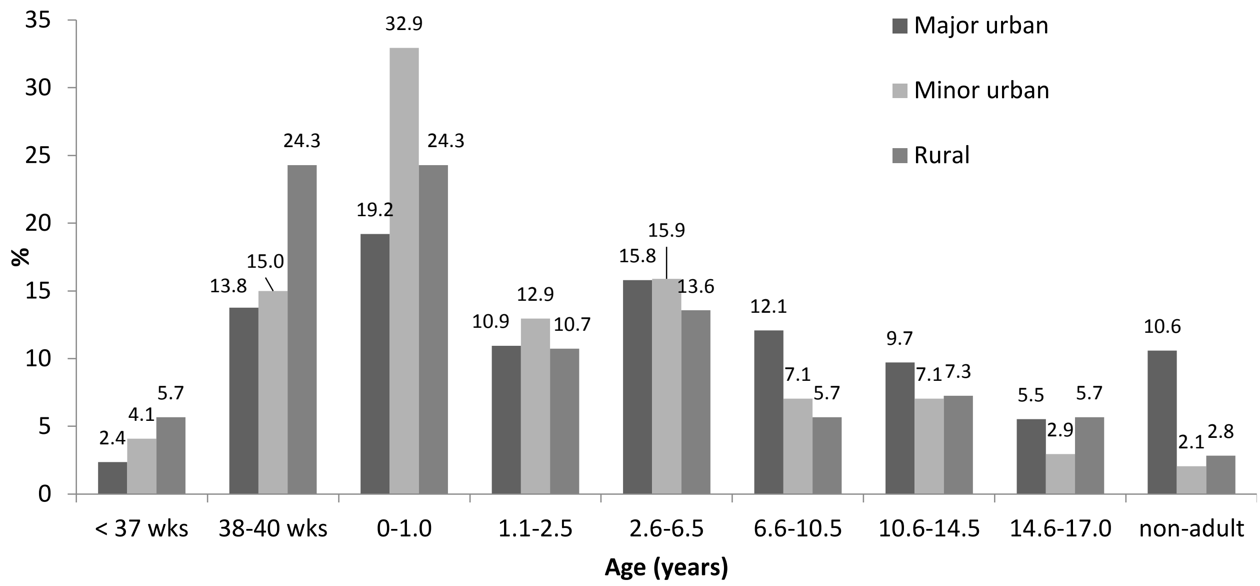


Figure 5.1. Ages-at-death of Romano-British non-adults in the combined study sample

Perinatal mortality is significantly higher in rural burial grounds than in major urban cemeteries (X^2=18.48, p<0.001, d.f.=1) and only just falls short of statistical significance when compared to minor urban cemeteries (X^2 =10.33, p<0.01, d.f.=1). In minor urban cemeteries, infant deaths are significantly higher than in major urban sites (X^2=30.64, p<0.001, d.f.=1). In the 6.6-10.5 year age category, more individuals were found in major urban environments compared to rural cemeteries, although the distribution is not significant at the 99.9% level (X^2 =10.53, p<0.01, d.f.=1) (Fig. 5.1).

5.2.2. Palaeopathology

The evaluation of palaeopathology includes skeletal pathologies, stress indicators and enamel hypoplasia. Dental disease was excluded from this part of analysis due to the separate pathogenesis of shortcomings in dental health. Lesions were observed in 552 (33.6%) individuals. There are significantly more pathological individuals in the major urban assemblage (37.4%, n=331) than the rural cohort (26.2%, n=83; X^2=13.00, p<0.001, d.f.=1) (Fig. 5.2).

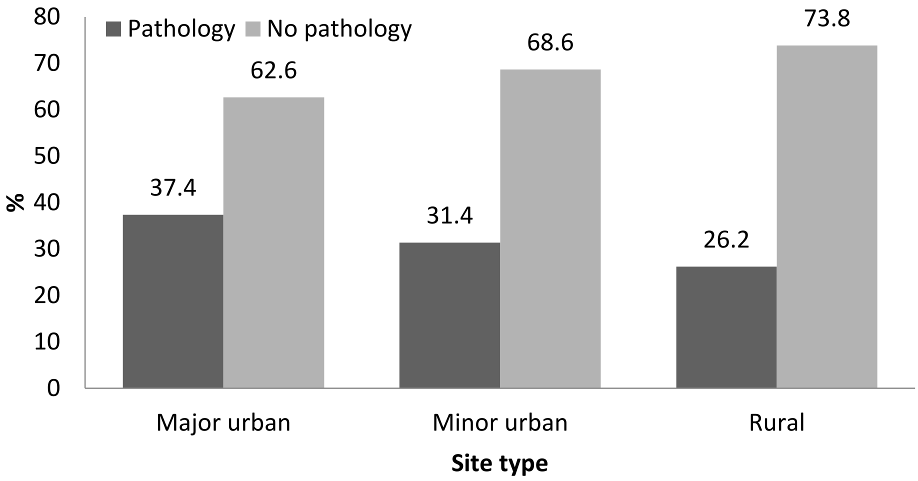


Figure 5.2. Distribution of observed pathologies across all site types (CPR)

Due to the nature of the skeletal data extracted from reports and the published and unpublished literature, it was only possible to differentiate crude prevalence rates for cribra orbitalia, enamel hypoplasia, metabolic disease and non-specific infection in the major urban, minor urban and rural cohorts (Table 5.2). All counts of cribra orbitalia were included in the analysis when referred to as present in the site report, regardless of severity. It is recognised that some of the incidences of cribra orbitalia contained in this category do not reflect Stuart-Macadam's (1991) scores of 3 to 5. The percentage distributions of enamel hypoplasia are based on individuals aged to 1.1 years and older. Infants and neonates have been excluded to avoid underrepresentation of the stress marker due to the formation and eruption patterns of the deciduous dentition. Similarly, the rates for infections of non-specific origin include individuals older than 1.1 years. Infants and neonates may display periosteal reactions that mimic infection but are a result of the rapid growth within this age group (Shopfner 1966; Weston 2008). Only older individuals were included where a clear distinction between growth and the relevant indicator of non-specific infection could be made.

Table 5.2. Crude prevalence rates of pathological lesions in the combined dataset

	Major urban		**Minor urban**		**Rural**		**Total**	
	n	%	n	%	n	%	**n**	**%**
Cribra orbitalia	102	11.5	41	9.3	31	9.8	**174**	**10.6**
Enamel hypoplasia	132	17.8	43	12.3	13	9.8	**188**	**14.2**
Metabolic disease	96	10.8	29	6.6	28	8.8	**153**	**9.3**
Non-specific infection	60	10.5	43	20.4	21	14.5	**124**	**13.4**
Total N	**886**		**440**		**317**		**1643**	

% of the cohort by site type

Crude prevalence rates vary across site types (Fig. 5.3). Metabolic disease and non-specific infection differ between the major and minor urban cohorts. There is a trend for more individuals from major urban settlements (10.8%, n=96) reported with metabolic disease than their minor urban peers (6.6%, n=29; X^2=6.35, p<0.05, d.f.=1). There is a statistical distribution in rates of enamel hypoplasia, where all three site types differ significantly from one another (X^2=28.95, p<0.001, d.f.=2), with the highest frequency in the major urban sample (17.8%, n=132) and the lowest in the rural cohort (5.9%, n=13). No statistical difference was found in the distribution of cribra orbitalia (X^2=1.88) or non-specific infection (X^2=4.23) between site types.

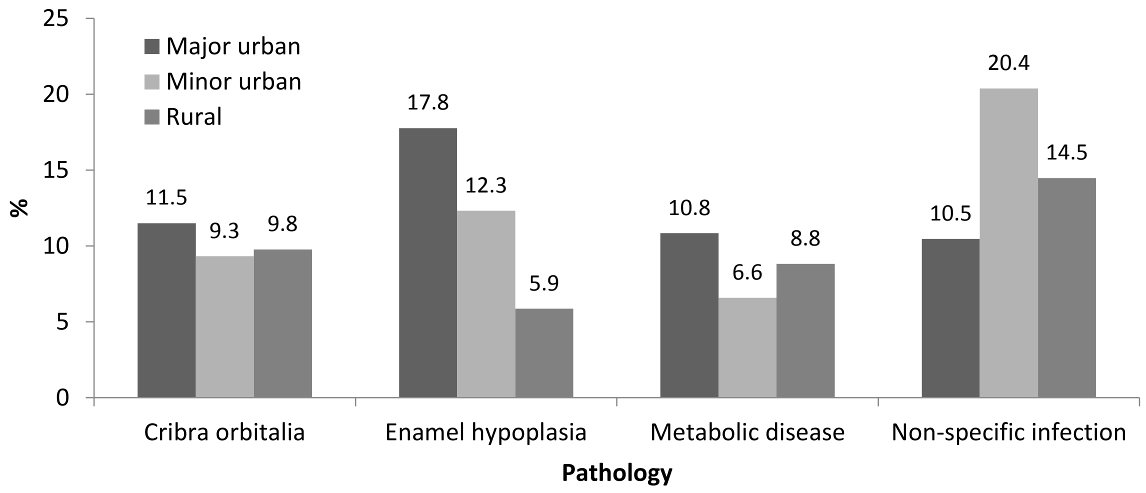


Figure 5.3. Crude prevalence rates of pathological lesions in the combined study sample

5.3. THE PRIMARY STUDY SAMPLE

The primary study sample only contains the palaeopathological and age-at-death data recorded by the author. This dataset includes 953 individuals from five major urban (41.1%, n=392), six minor urban (36.6%, n=349) and four rural sites (22.3%, n=212). Similar to the combined study sample, there is a bias towards more individuals from major urban sites.

5.3.1. Age-at-death

There were 31 individuals (3.3%) that could not be assigned an age category due to preservation and fragmentation, these were included in the 'non-adult' age category (Table 5.3).

Table 5.3. Distribution of ages-at-death in the primary study sample

Age	Major urban		Minor urban		Rural		Total	
	n	%	*n*	%	*n*	%	***n***	**%**
< 37 wks	20	5.1	14	4.0	16	7.6	**50**	**5.3**
38-40 wks	61	15.6	56	16.1	27	12.7	**144**	**15.1**
0-0.5	57	14.5	46	13.2	49	23.1	**152**	**15.9**
0.6-1.0	8	2.0	31	8.9	17	8.0	**56**	**5.9**
1.1-2.5	42	10.7	56	16.1	24	11.3	**122**	**12.8**
2.6-6.5	62	15.8	68	19.5	32	15.1	**162**	**16.9**
6.6-10.5	44	11.2	30	8.6	11	5.2	**85**	**8.9**
10.6-14.5	48	12.2	29	8.3	20	9.4	**97**	**10.2**
14.6-17.0	28	7.1	11	3.2	15	7.1	**54**	**5.7**
Non-adult	22	5.6	8	2.3	1	0.5	**31**	**3.3**
Total	**392**		**349**		**212**		**953**	

% of the cohort by site type

There are elevated mortality rates in perinates aged to 38-40 weeks gestation (15.1%, n=144) and neonatal individuals aged from birth up to six months old (15.9%, n=152). There is a sharp decline in deaths in later infancy (5.9%, n=56). Mortality rises again in 1.1-2.5-year olds (12.8%, n=122) and peaks at 2.6-6.5 years (16.9%, n=162). The mortality rate then drops by almost half in the 6.6-10.5 year age group (8.9%, n=85), and is again elevated in 10.6-14.5-year olds (10.2%, n=97), with a final decrease to 5.7% (n=54) in 14.6-17.0-year olds (Table 5.3).

More 0-0.5-year olds were recorded from rural sites, compared to the urban burial grounds, although the result is not significant at the 99.9% level (23.1%, n=49; X^2=10.56, p<0.01, d.f.=2). From six months to one year old, there are significantly fewer individuals in the major urban cohort (2.0%, n=8; X^2=17.72, p<0.001, d.f.=2). In 6.6-10.5-year olds, there was a trend for proportionately more individuals in the major urban (11.2%, n=44) as opposed to the rural sites (5.2%, n=11; X^2=6.26, p<0.05, d.f.=1). There is also a trend for fewer 14.6-17.0-year olds from minor urban sites (3.2%, n=11; X^2=6.5 p<0.05, d.f.=2) (Fig. 5.4).

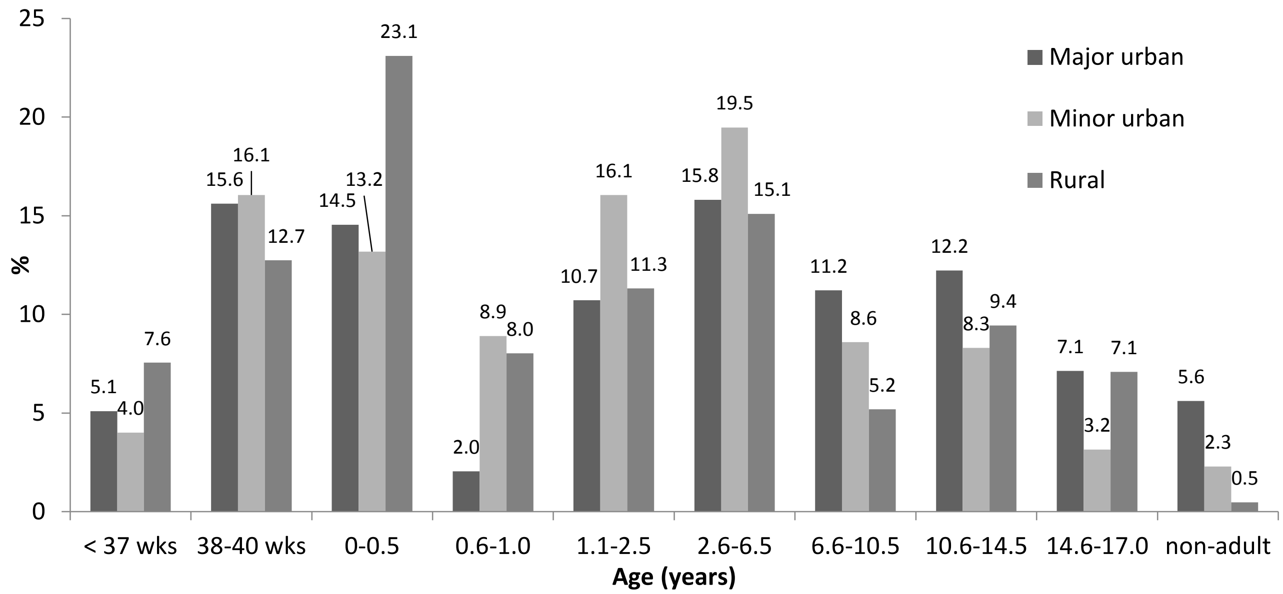


Figure 5.4. Ages-at-death of Romano-British non-adults in the primary study sample

5.3.2. The perinates

Mortality profiles of perinatal individuals only include those that could be aged according to Scheuer et al.'s (1980) long bone regression formulae (n=187). The majority of deaths occurred around full term at 38-40 gestational weeks (9.0%, n=129) (Table 5.4 and Fig. 5.5). The youngest identified individual is a 24-week-old foetus from a 3rd century AD context at rural Owslebury, Hampshire.

Figure 5.6 presents the proportions of neonatal and post-neonatal deaths as percentages of the total of perinatal deaths, following Bourgeois-Pichat's (1951) model of endogenous and exogenous causes of infant mortality. Preterm deaths include any individual at 37 weeks gestation or younger, although this group may also include individuals that are small for gestational age (Lewis and Gowland 2007).

Table 5.4. Gestational age of perinatal deaths by site type

Gestational age	Major urban		Minor urban		Rural		Total	
	n	*%*	*n*	*%*	*n*	*%*	***n***	***%***
23-25 wks	0	0	0	0	1	2.8	**1**	**0.5**
26-28 wks	0	0	0	0	1	2.8	**1**	**0.5**
29-31 wks	0	0	3	4.5	2	5.6	**5**	**2.7**
32-34 wks	1	1.2	3	4.5	2	5.6	**6**	**3.2**
35-37 wks	19	22.4	7	10.6	10	27.8	**36**	**19.3**
38-40 wks	61	71.8	48	72.7	20	55.6	**129**	**69.0**
41-43 wks	0	0	3	4.5	0	0	**3**	**1.6**
44-46 wks	4	4.7	2	3.0	0	0	**6**	**3.2**
Total	**85**		**66**		**36**		**187**	

% of cohort by site type

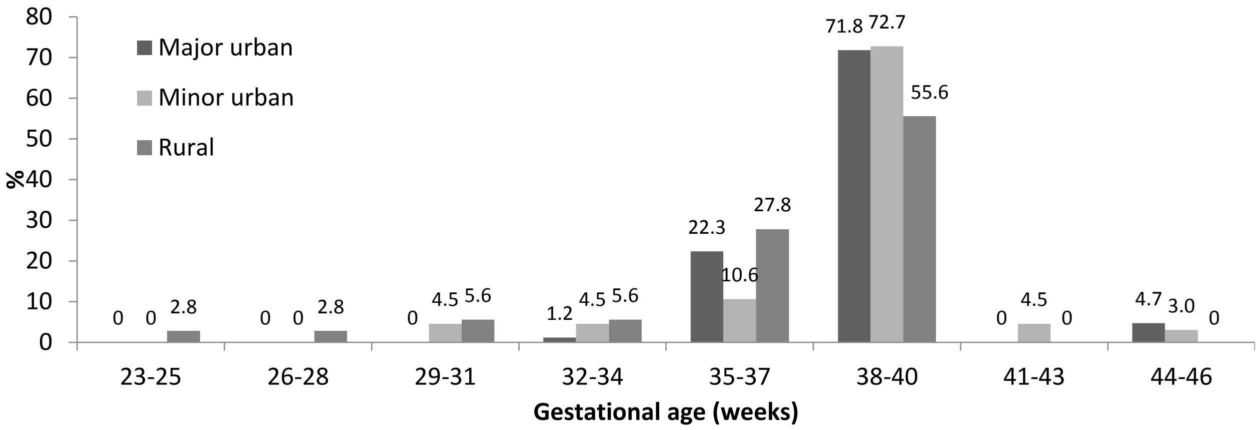


Figure 5.5. Perinatal mortality

We are currently unable to distinguish between premature deaths, stillbirths, or babies that have lived for a few days postpartum on a large scale (Saunders and Barrans 1999, 185-187). Therefore all individuals up until 40 weeks gestation were classed as neonates, and babies over 41 weeks were assigned to the post-neonatal age group (Scheuer and Black 2004, 4; Lewis and Gowland 2007; Swamy et al. 2008). No post-neonatal deaths have been reported for the rural sample. The highest frequency of post-neonatal deaths was recorded in the minor urban sample at 7.6% (n=5) (Table 5.5). There is no statistical difference in the relative frequencies of neonatal and post-neonatal deaths when comparing their ratios between site types (X^2=3.56) (Fig. 5.6).

Table 5.5. Neonatal and post-neonatal mortality

	Neonatal		Post-neonatal	
	n	%	*n*	%
Major urban	81	95.3	4	4.7
Minor urban	61	92.4	5	7.6
Rural	36	100	0	0
Total	**178**	**95.2**	**9**	**4.8**

% of the total of perinatal deaths by site type

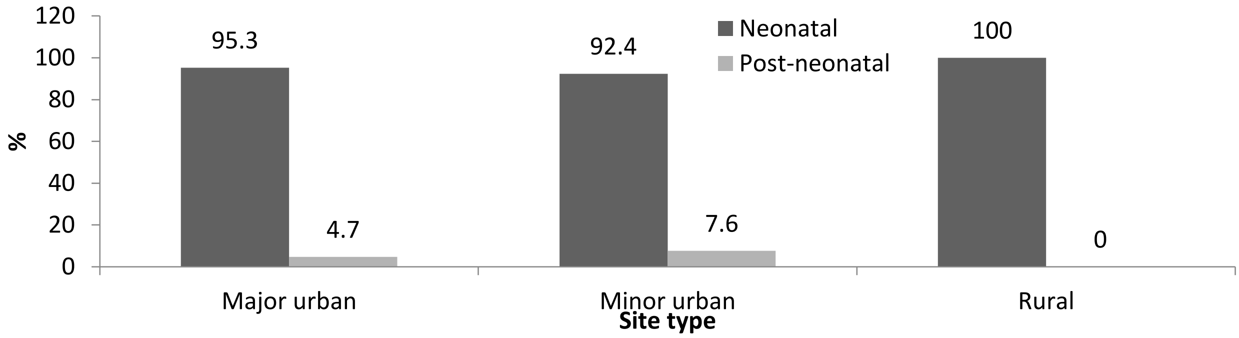


Figure 5.6. Relative frequencies of neonatal and post-neonatal deaths by site type

5.3.3. Growth profiles

A total of 637 long bone measurements were taken from 256 major urban, 333 minor urban and 48 rural individuals. The summary growth data are displayed in A6.1 to A6.5 in Appendix VI in one year age intervals. The growth data provided in Maresh (1955) was also tabulated in one year intervals, with averages for boys and girls (A6.6 in Appendix VI). The curves comparing Romano-British and modern skeletal growth data are presented in Figures 5.7 to 5.11 for humeral, radial, ulnar, femoral and tibial mean diaphyseal measurements. It is evident from the graphs that Romano-British children exhibited shorter mean diaphyseal lengths throughout compared to Maresh's (1955) study population. After around 13 years old, the Romano-British growth curves further tail off from those of the modern children. Two-tailed Kolmogorov-Smirnov tests were applied to test for differences in the distribution of long bone length between the Romano-British and modern samples. No statistical significance in the deviation of the Romano-British from the modern data for humeral (KS=0.857, p=0.454), radial (KS=0.707, p=0.699), ulnar (KS=0.707, p=0.699), femoral (KS=0.884, p=0.415) and tibial (KS=0.884, p=0.415) mean diaphyseal lengths was found (Appendix IV).

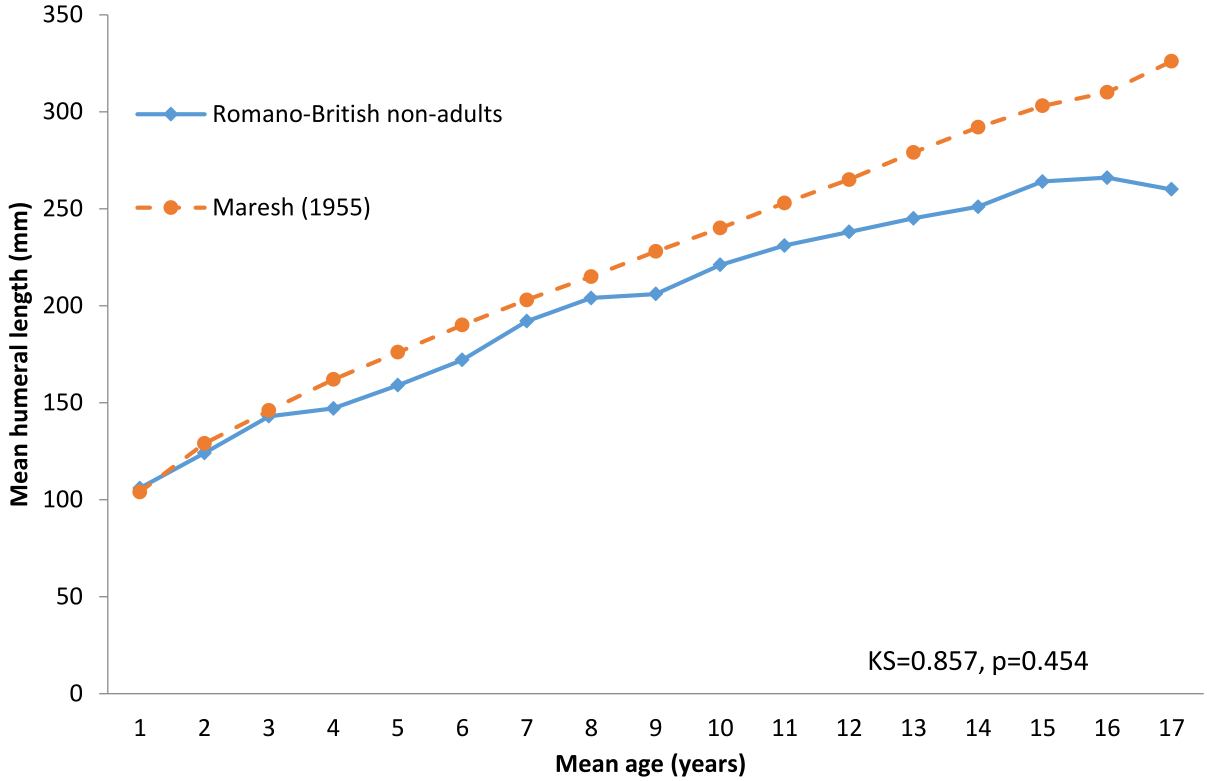


Figure 5.7. Romano-British and modern mean humeral diaphyseal lengths

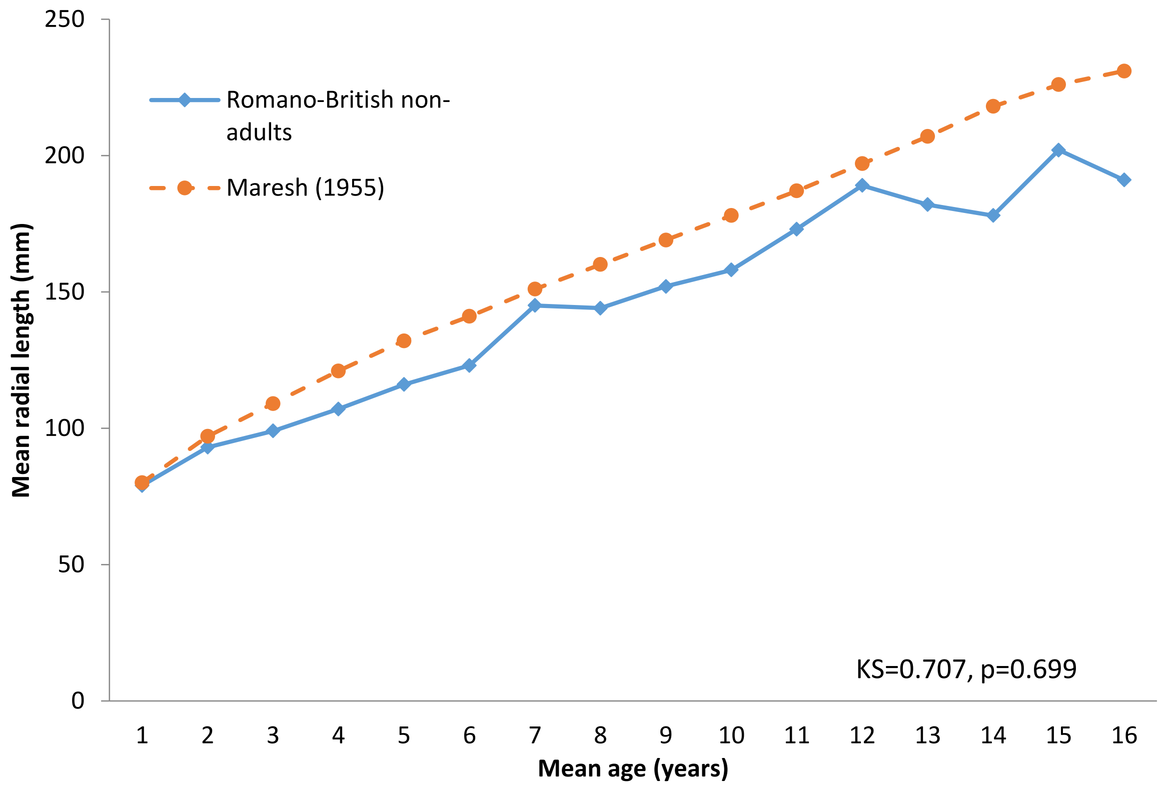


Figure 5.8. Romano-British and modern mean radial diaphyseal lengths

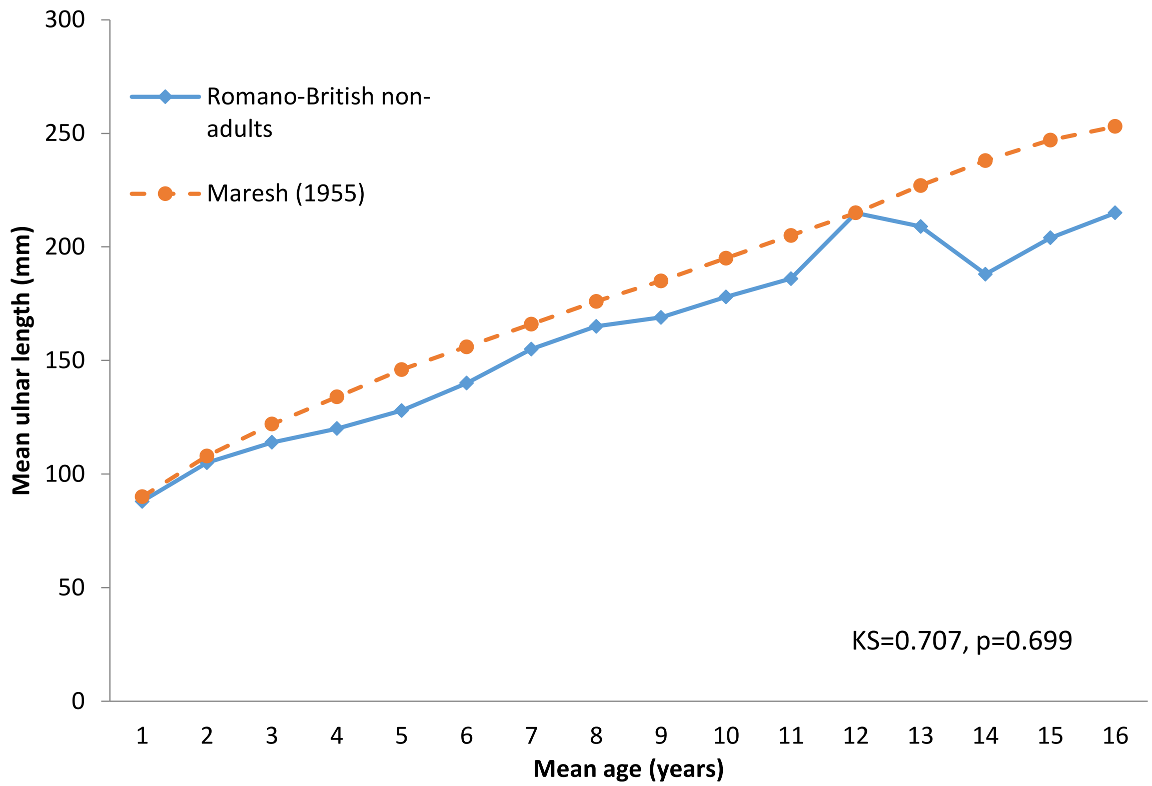


Figure 5.9. Romano-British and modern mean ulnar diaphyseal lengths

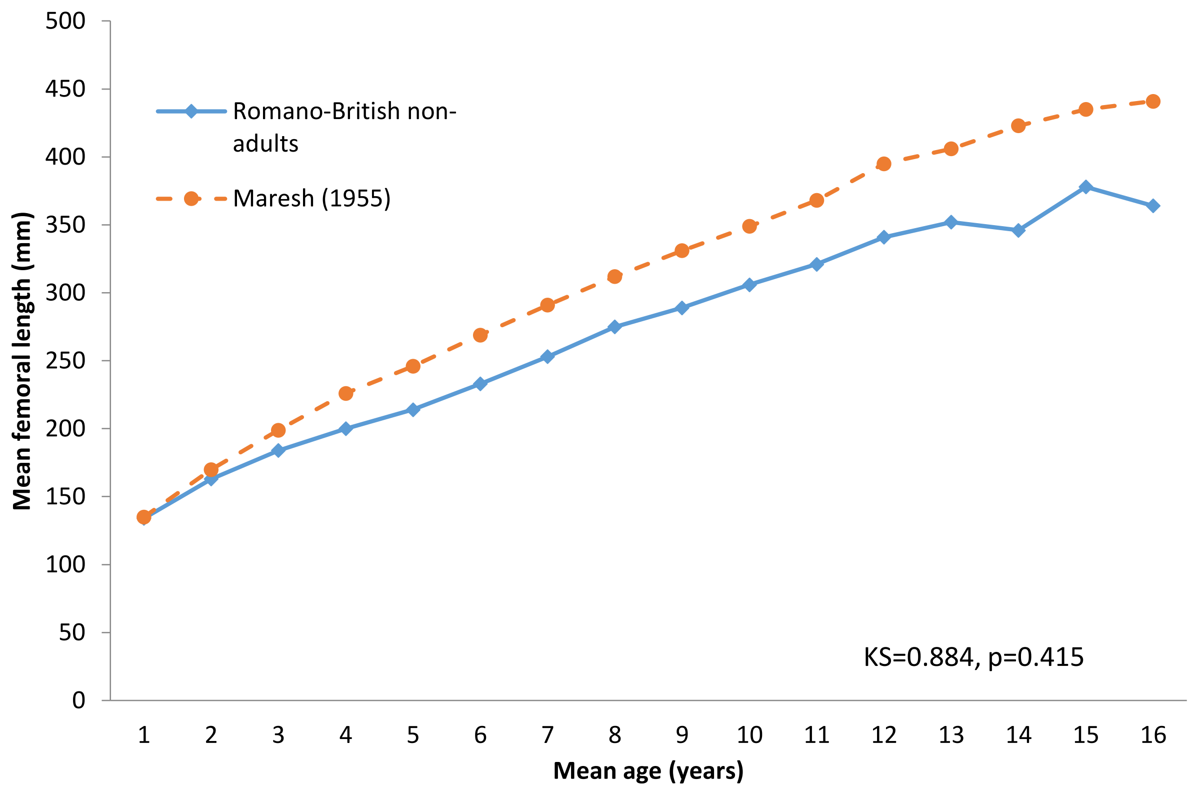


Figure 5.10. Romano-British and modern mean femoral diaphyseal lengths

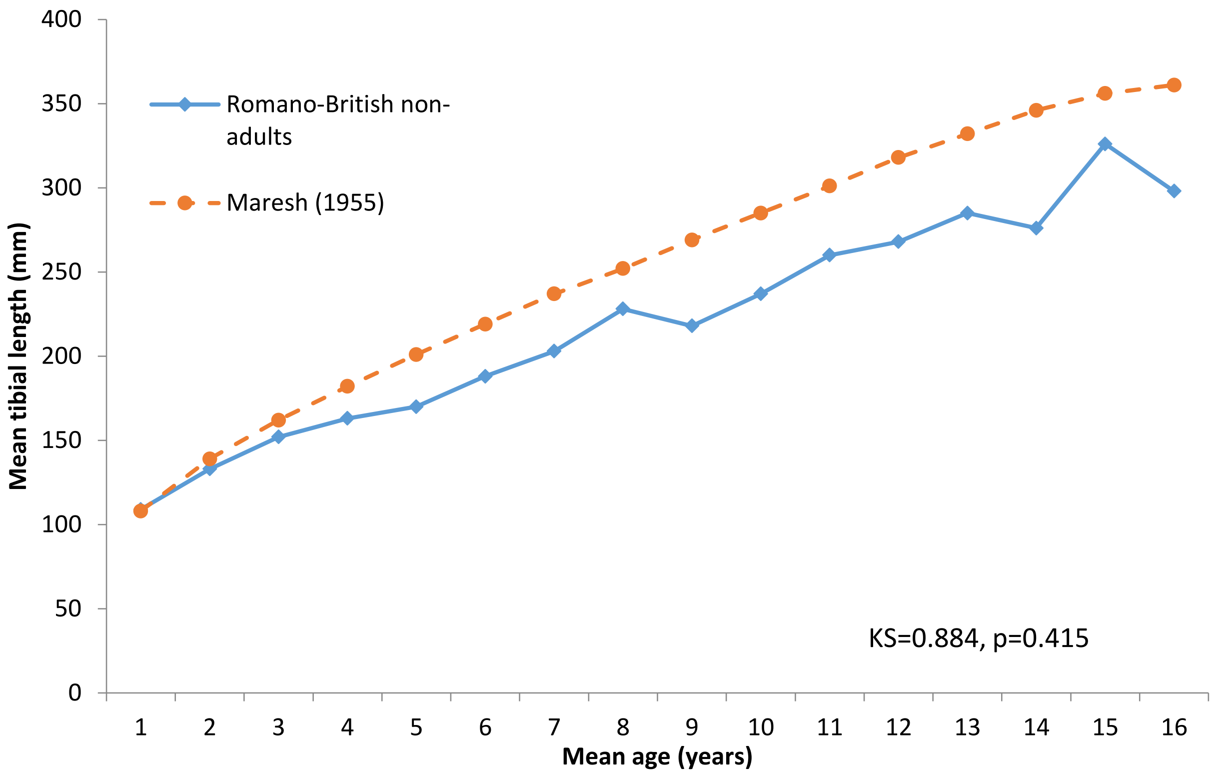


Figure 5.11. Romano-British and modern mean tibial diaphyseal lengths

Femoral diaphyseal lengths for the three different site types are tabulated in A6.7 (in Appendix VI). A scatterplot with the regression line for the three non-adult samples is shown in Fig. 5.12 below. The Kruskal-Wallis one-way analysis of variance was used to explore statistically significant differences in femoral growth between the three groups. There is no statistically significant difference in femoral length between the major urban, minor urban and rural cohort (K=1.19, p=0.552, d.f.=2).

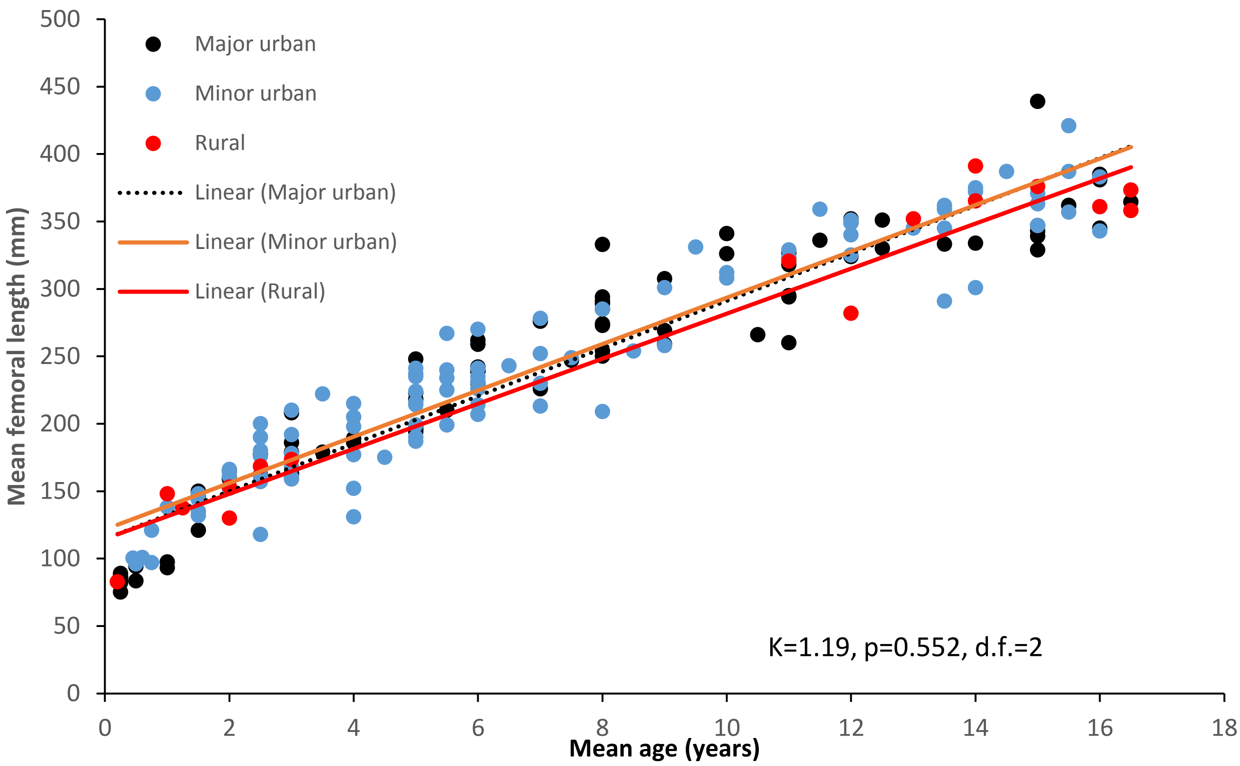


Figure 5.12. Femoral length in across major urban, minor urban and rural sites

5.3.4. Palaeopathology

5.3.4.1. Dental disease

Dental disease was recorded in 18.5% (n=35) of major urban, 15.1% (n=25) of minor urban and 5.1% (n=4) of rural individuals who presented with erupted dentition. There is merely a trend for a lower crude prevalence rate of dental disease in the rural cohort (X^2=8.24, p<0.05, d.f.=2). True prevalence rates of caries were calculated for the total of erupted teeth (Table 5.6). Counts of the numbers of erupted teeth available for each individual settlement context are tabulated in A3.4 (in Appendix III). There is a trend in crude prevalence rates of caries towards higher rates in urban sites, although this is not statistically significant (X^2=7.08).

The caries correction factor (Lukacs 1995) was not factored into the presentation of caries rates, as merely true prevalence rates were sought. This will also allow for easier comparison with previously published work on caries in Romano-British non-adults. It is also highly likely that post-mortem tooth loss will have altered caries frequencies, and this would be a point that could be further explored in future work on dental health and oral infections in non-adults from Roman Britain.

The true prevalence rates of carious lesions differ significantly between the urban and rural site types. Caries is significantly higher in the major urban (TPR 1.8%, n=49) compared to the rural sample (TPR 0.4%, n=4; X^2=12.06, p<0.001, d.f.=1) (Table 5.6). Crude prevalence rates of antemortem tooth loss (AMTL), periapical lesions (PAL) and all other dental anomalies were calculated out of the total of individuals with alveolar bone present (Table 5.7). The category 'other' describes any other dental anomaly including congenital fusion of teeth, non-vital teeth, impacted teeth and congenital absence of a tooth (hypodontia) (Hillson 1993; Watts and Addy 2001). No abscesses or teeth lost antemortem were recorded in the rural cohort. There is no statistical difference in the distribution of periapical lesions, antemortem tooth loss and miscellaneous dental anomalies between the sites (Table 5.7).

Yule's Q was calculated to measure the association between carious lesions and enamel hypoplasia in erupted teeth, indicating a strong association between carious lesions and hypoplastic enamel defects (Q=0.75) (Cook and Buikstra 1979; Duray 1992, 315-316). A total of 309 out of 2700 teeth (TPR 11.4%) from major urban non-adults displayed enamel defects. In minor urban contexts, 236 of 2460 teeth showed hypoplasia (TPR 9.6%) and total of 1087 teeth from rural sites yielded 49 teeth with enamel hypoplasia (TPR 4.5%). The rural true prevalence rate is significantly lower than those from urban contexts (X^2=43.66, p<0.001, d.f.=2). The higher rates of enamel hypoplasia observed in major urban non-adults (TPR 11.4%) also match the elevated rates of carious lesions in these settlements. A total of 19 children with caries were also affected by enamel hypoplasia. The crude prevalence rate of those with both enamel defects and carious lesions was highest in major urban sites at CPR 5.8% (n=11/189) and minor urban sites at CPR 4.2% (n=7/165), and lowest in rural children at CPR 1.3% (n=1/78). The distribution is not significant (X^2=3.26).

Table 5.6. True prevalence rates of caries

	Major urban		**Minor urban**		**Rural**		**Total**	
	n	*%*	*n*	*%*	*n*	*%*	***n***	***%***
Caries	49 (28)	1.8 (14.8)	37 (18)	1.5 (10.4)	4 (3)	0.4 (3.8)	**90 (49)**	**1.4 (11.3)**
Total N	**2724 (189)**		**2472 (166)**		**1087 (78)**		**6283 (433)**	

% of erupted teeth in cohort by site type; CPR in brackets for individuals with at least one erupted tooth

Table 5.7. Crude prevalence rates of other dental disease rates

	Major urban		Minor urban		Rural		Total	
	n	%	*n*	%	*n*	%	***n***	**%**
PAL	4[1]	1.4	4[1]	1.7	0[1]	0	**9[1]**	**1.4**
AMTL	4[1]	1.4	2[1]	0.8	0[1]	0	**6[1]**	**0.9**
Other	1[2]	0.5	4[2]	2.3	2[2]	2.4	**7[2]**	**1.6**
Total	**289[1]**		**242[1]**		**121[1]**		**652[1]**	

% of the cohort by site type; [1]individuals with alveolar bone; [2]out of the total of individuals with dentition present

True prevalence rates for caries differ in the deciduous and permanent dentition (Table 5.8). In major urban sites, 65.3% (n=32) of teeth affected by carious lesions were deciduous, so were 51.4% (n=19) of those in minor urban sites, but only 25% (n=1) of carious lesions in rural sites. Caries in deciduous teeth occurs at significantly higher rates in major urban sites (TPR 3.0%, n=32) compared to rural settlements (TPR 0.2%, n=1; X^2=12.8, p<0.001, d.f.=1). In the permanent dentition, the highest rate of caries was found in the minor urban cohort (TPR 1.6%, n=18).

For the total sample, caries occurred at a significantly higher rate in the posterior dentition (TPR 2.3%, n=83; X^2=42.65, p<0.001, d.f.=1). The caries rate in posterior teeth from rural settlements (TPR 0.6%, n=4) is significantly lower than the rate in major urban contexts (TPR 2.9%, n=47; X^2 =11.67, p<0.001, d.f.=1) (Table 5.8).

Considering the deciduous dentition separately, caries was more prevalent in posterior teeth (TPR 2.7%, n=45; X^2=18.71, p<0.001, d.f.=1). Between the site types, the distribution of caries in the posterior deciduous dentition is statistically significant. No case of caries was recorded in the posterior deciduous teeth from rural sites. This rate is significantly lower than the prevalence rate in major urban sites (TPR 4.8%, n=30; X^2=12.24, p<0.001, d.f.=1) Table 5.9). Exclusively posterior teeth were affected by caries in permanent teeth (TPR 1.9%, n=38), this rate is statistically significant with X^2=26.13 (p<0.001, d.f.=1). The highest frequency of caries was found in the posterior teeth of minor urban non-adults (TPR 2.8%, n=18) (Table 5.9).

Caries affecting the root of a tooth was reported in only one case, a 15-year old from minor urban Dunstable with caries in the mandibular dentition, leading to complete destruction of the crown of the left first permanent molar, and involvement of the root. No lesions at the cemento-enamel junction were reported. Caries was predominantly found on the occlusal surface of posterior teeth (TPR 1.1%, n=39/3678). Fissure caries accounted for 49.4% (n=39/79) of caries in posterior teeth. Interproximal caries affecting the crown surface either mesially or distally was reported in 29 posterior teeth from major urban and minor urban sites (TPR 1.0%, n=29/3019), affecting 38.7% (n=29/75) of posterior carious teeth from urban non-adults. Buccal caries was reported in the major urban and minor urban cohorts only, at TPR 0.3% (n=8/3019), affecting 10.7% (n=8/75) of posterior carious teeth in the urban samples.

Table 5.8. True prevalence rates of caries by erupted tooth type: deciduous, permanent, anterior and posterior

	Major urban				**Minor urban**				**Rural**				**Total**			
	Deciduous		Permanent		Deciduous		Permanent		Deciduous		Permanent		**Deciduous**		**Permanent**	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	***n***	**%**	***n***	**%**
Caries	32	3.0	17	1.0	19	1.4	18	1.6	1	0.2	3	0.5	**52**	**1.8**	**38**	**1.1**
Total N	**1075**		**1649**		**1354**		**1118**		**481**		**606**		**2910**		**3373**	
	Anterior		Posterior		Anterior		Posterior		Anterior		Posterior		**Anterior**		**Posterior**	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	***n***	**%**	***n***	**%**
Caries	2	0.2	47	2.9	5	0.5	32	2.3	0	0	4	0.6	**7**	**0.3**	**83**	**2.3**
Total N	**1100**		**1624**		**1069**		**1403**		**428**		**659**		**2597**		**3686**	

% of the cohort by site type

Table 5.9. True prevalence rates of caries in the deciduous and permanent dentition by tooth type

	Major urban				**Minor urban**				**Rural**				**Total**			
Deciduous	Anterior		Posterior		Anterior		Posterior		Anterior		Posterior		**Anterior**		**Posterior**	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	***n***	**%**	***n***	**%**
Caries	2	0.5	30	4.8	5	0.8	14	1.9	0	0	1	0.4	**7**	**0.6**	**45**	**2.7**
Total N	**448**		**627**		**599**		**755**		**196**		**285**		**1243**		**1667**	
Permanent	Anterior		Posterior		Anterior		Posterior		Anterior		Posterior		**Anterior**		**Posterior**	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	***n***	**%**	***n***	**%**
Caries	0	0	17	1.7	0	0	18	2.8	0	0	3	0.8	**0**	**0**	**38**	**1.9**
Total N	**652**		**997**		**470**		**648**		**232**		**374**		**1354**		**2019**	

% of the cohort by site type

The distribution of carious lesions differs between age groups (Table 5.10). The highest frequency of caries was reported in the 6.6-10.5 year age group (TPR 2.3%, n=24), with the lowest rate in the 1.1-2.5 year age groups (TPR 0.1%, n=1). It is of note that nine (56.3%) of the 16 teeth affected by caries in the minor urban cohort in the 2.6-6.5-year olds stem from a 3-year old at Ancaster with severe early childhood caries in the maxillary dentition (Azevedo et al. 2005; Bonsall et al. 2015) (Fig. 5.13). In 6.6-10.5-year olds, the prevalence of caries is statistically higher in the urban samples (X^2=11.36, p<0.005, d.f.=2) (Fig. 5.14).

Table 5.10. True prevalence rates of caries by age and site type

	Major urban			**Minor urban**			**Rural**			**Total**		
Age (yrs)	*n*	*%*	*N*	*n*	*%*	*N*	*n*	*%*	*N*	***n***	***%***	***N***
1.1-2.5	1	0.3	394	0	0	571	0	0	193	**1**	**0.1**	**1158**
2.6-6.5	12	2.2	555	16	2.0	792	0	0	254	**28**	**1.8**	**1601**
6.6-10.5	20	3.7	539	4	1.0	393	0	0	112	**24**	**2.3**	**1044**
10.6-14.5	11	1.3	883	11	2.1	520	1	0.3	315	**23**	**1.3**	**1718**
14.5-17.0	5	2.4	213	6	3.1	195	3	0.9	351	**14**	**1.8**	**759**
Total	**49**	**1.8**	**2724**	**37**	**1.5**	**2472**	**4**	**0.4**	**1087**	**90**	**1.4**	**6283**

% of cohort in individual age group by site type

Figure 5.13. Anterior view of rampant caries on the maxillary deciduous teeth of a 3-year old. From Ancaster, skeleton 233. (from Bonsall et al. 2015)

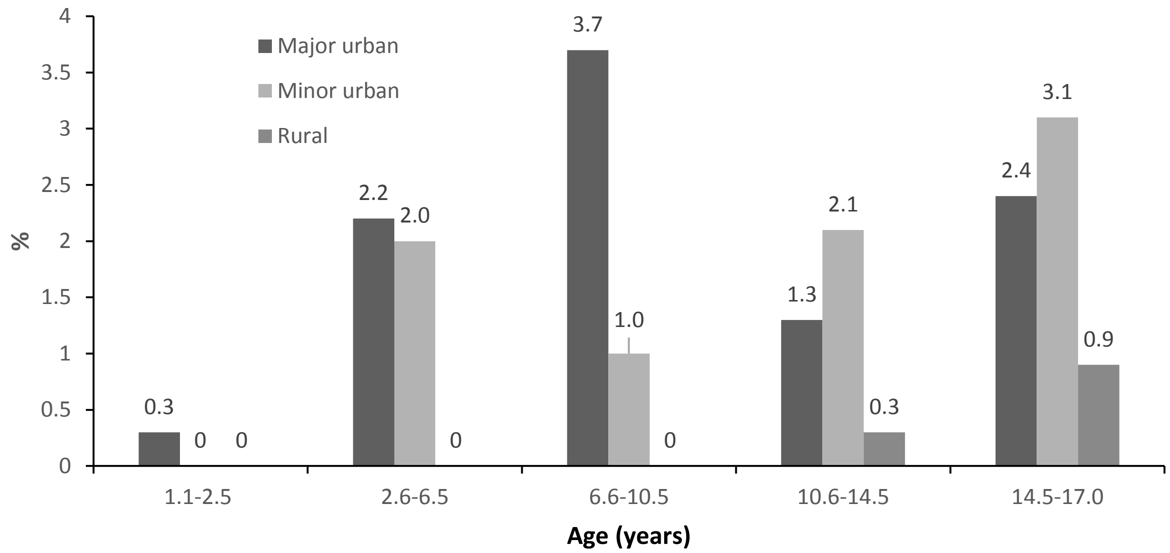


Figure 5.14. True prevalence rates of caries by age

5.3.4.2. Overview of total of skeletal lesions

Enamel hypoplasia and skeletal palaeopathological lesions were recorded in 350 individuals (37.2% CPR). A total of 12 individuals (major urban n=4, minor urban n=5, rural n3) were insufficiently preserved or too fragmentary to display any skeletal lesions. The distribution of pathology between the major urban, minor urban and rural cemeteries is similar (Table 5.11).

Table 5.11. Crude prevalence of the overall distribution of pathology

	Pathology		**No Pathology**		**Total**
	n	*%*	*n*	*%*	***N***
Major urban	138	35.6	250	64.4	**388**
Minor urban	134	38.9	210	61.1	**344**
Rural	78	37.3	78	62.7	**209**
Total	**350**	**37.2**	**591**	**62.8**	**941**

% of cohort by site type

5.3.4.3. Palaeopathology overview across the site types

Prevalence rates for different skeletal lesions and enamel hypoplasia are tabulated in Table 5.12. The rate of enamel hypoplasia refers to hypoplastic lesions in individuals with at least two anterior teeth present, and several enamel defects per individual are scored as one count (CPR). Non-specific infections (CPR) include diagnoses of osteomyelitis, endocranial lesions and sub-periosteal new bone formation. Skeletal indicators of non-specific infection apply to individuals aged 0.6 years and over, and when the lesion was not attributed to a more widespread specific infection, metabolic disease, neoplastic disease or congenital disorder (Shopfner 1966; Lewis and Roberts 1997; Lewis 2004; Weston 2008).

There are merely trends in the distribution of lesions between the three site types, rather than statistically significant differences (Fig. 5.15). Cribra orbitalia Grade 3 and above was recorded in 36 major urban individuals, with 16.1% the lowest TPR, and there is merely a trend for higher rates in rural sites (TPR 27.7%, n=28; X^2=5.74, p<0.05, d.f.=1). The lowest crude prevalence rate of enamel hypoplasia was found in the rural non-adults (11.4%, n=12), and the rate is doubled in urban sites (25.2%, n=54; X^2=8.41, p<0.05, d.f.=2). Metabolic disease was recorded in 31 (CPR 8.2%) major urban, 28 (CPR 8.6%) minor urban and 27 (CPR 13.4%) rural individuals. Although the distribution is not statistically significant, the higher rate of metabolic disease in rural non-adults is still of interest (Table 5.12). Infections of non-specific origin were observed in 27 (CPR 8.7%) major urban, 45 (CPR 13.7%) minor urban, and 18 (CPR 13.3%) rural individuals. Probable and possible cases of tuberculosis were diagnosed in three (CPR 1.9%) major urban individuals, two (CPR 1.3%) minor urban individuals, and one (CPR 1.2%) rural non-adult, the distribution is not significant (X^2=1.38). Antemortem trauma was identified in seven (CPR 1.8%) major urban, five (CPR 1.5%) minor urban and four (CPR 1.9%) rural individuals. Possible cases of thalassaemia were recorded in major urban sites only, with one case from the Butt Road cemetery in Colchester (skeleton 864) and two individuals from 35 Kingsholm Road in Gloucester (skeletons 362 and 367). Two individuals from the major and minor urban contexts exhibited evidence for congenital disease, 0.6% crude prevalence for both site types, and three rural non-adults (CPR 1.6%) have been recorded with signs for congenital disease. The cases labelled ‘other’ categorise all other lesions and include vertebral anomalies, osteochondritis dissecans, ankylosis, and any other lesion that could not be attributed to the categories used (Schenk and Goodnight 1996; Aufderheide and Rodriguez-Martin 1998; Ortner 2003). No statistical tests were undertaken for these groups as the samples are too small to yield meaningful results, and distributions are similar across the sites types.

Table 5.12. Crude prevalence rates of pathological lesions across the three site types

	Major urban			Minor urban			Rural			Total		
	n	*%*	*N*	*n*	*%*	*n*	*n*	*%*	*N*	***n***	***%***	***N***
Enamel hypoplasia[1]	54	25.2	214	43	22.4	192	12	11.4	105	**109**	**21.3**	**511**
Non-specific infection	27	10.6	254	45	19.3	233	18	15.0	120	**90**	**14.8**	**607**
Cribra orbitalia[2]	36	16.1	223	40	21.5	186	28	27.7	101	**104**	**20.4**	**510**
Metabolic disease	31	8.2	378	28	8.6	327	27	13.4	202	**86**	**9.5**	**907**
Thalassaemia	3	1.0	314	0	0	313	0	0	178	**3**	**0.4**	**805**
Tuberculosis	3	1.9	161	2	1.3	157	1	1.2	84	**6**	**1.5**	**402**
Trauma	7	1.8	388	5	1.5	344	4	1.9	209	**16**	**1.7**	**941**
Congenital disease	2	0.6	319	2	0.6	316	3	1.6	184	**7**	**0.9**	**819**
Other	22	5.7	388	11	3.2	344	2	1.0	209	**35**	**3.7**	**941**

% of cohort by site type/total; [1]crude prevalence rate by individual with at least 2 anterior teeth present; [2]true prevalence rate by individual with at least one orbit present

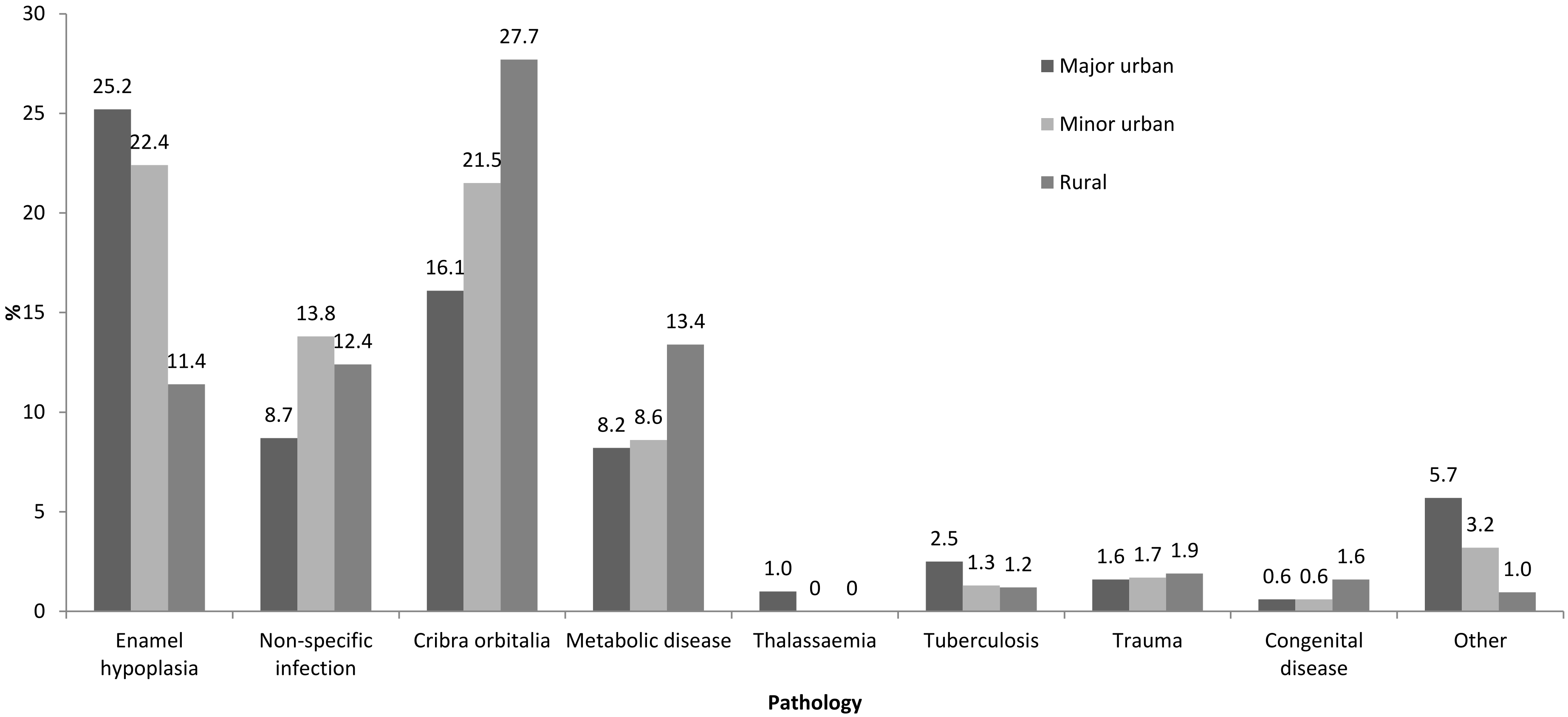


Figure 5.15. Distribution of pathologies by site type

5.3.4.4. Indicators of non-specific stress

5.3.4.4.1. Enamel hypoplasia

The crude prevalence rates of enamel hypoplasia in Table 5.13 and Figure 5.15 refer to enamel defects per individual with at least two anterior teeth present. Two or more teeth affected by a hypoplastic defect per individual were scored as one count of enamel hypoplasia. The highest rate for the overall sample was found in 10.6-14.5-year olds (CPR 44.1%, n=84), and the distribution across the age groups is statistically significant (X^2=62.42, p<0.001, d.f.=5).

Table 5.13. Crude prevalence rates of enamel hypoplasia by age

	Major urban			**Minor urban**			**Rural**			**Total**		
Age (yrs)	*n*	*%*	*N*	*n*	*%*	*N*	*n*	*%*	*N*	***n***	***%***	***N***
0-0.5	0	0	26	0	0	15	0	0	17	**0**	**0**	**58**
0.6-1.0	0	0	5	0	0	14	0	0	8	**0**	**0**	**27**
1.1-2.5	6	16.2	37	7	14.6	48	0	0	22	**13**	**12.2**	**107**
2.6-6.5	11	22.9	48	12	21.4	56	1	4.5	22	**24**	**19.1**	**126**
6.6-10.5	11	33.3	33	7	25.9	27	5	62.5	8	**23**	**33.8**	**68**
10.6-14.5	20	45.5	44	13	54.2	24	4	25.0	16	**37**	**44.1**	**84**
14.6-17.0	6	30	20	4	50.0	8	2	16.7	12	**12**	**30.0**	**40**
Non-adult	0	0	1	0	0	0	0	0	0	**0**	**0**	**1**
Total	**54**	**25.2**	**214**	**43**	**22.4**	**192**	**12**	**11.4**	**105**	**109**	**21.3**	**511**

% of cohort in individual age group by site type

Merely trends rather than statistically significant distributions in the crude prevalence rates of enamel hypoplasia have been observed in the different age groups between the site types. In 1.1-2.5-year olds, no count of enamel hypoplasia was found in rural non-adults, compared to 16.2% (n=6) in major urban and 14.6% (n=7) in minor urban non-adults. Similarly, in the 2.6-6.5 year age group, more individuals with enamel hypoplasia in the major urban sample (22.9%, n=11) have been reported compared to the rural sites (4.5%, n=1) (Fig. 5.16). There are a total of 18 individuals with circular enamel defects in the deciduous dentition, seven non-adults from minor urban settlements (5.1%) and 11 from major urban sites (3.6%), with none recorded in the rural cohort (X^2=6.12).

Across all three settlement types, non-adults without enamel hypoplasia were significantly younger at death than their peers with enamel defects (Table 5.31). In major urban assemblages, non-adults with enamel hypoplasia were an average age of 9.2±4.1 years, compared to those without enamel hypoplasia at 6.4±5.0 years. The difference of 2.8 years is statistically significant at the 99.8% level (KS=1.878, p=0.002). In minor urban settlements, non-adults with enamel hypoplasia died averaging 8.5±4.6 years, compared to those without the stress indicator who died at an average age of 4.6±4.0 years. The mean difference of 3.9 years is statistically significant (KS=2.200, p<0.001). Rural non-adults with enamel hypoplasia have an average age-at-death of 11.0±3.2 years, which is 5.5 years higher than the average age-at-death of those without enamel hypoplasia at 5.6±5.4 years. The difference is statistically significant (KS=2.032, p=0.001).

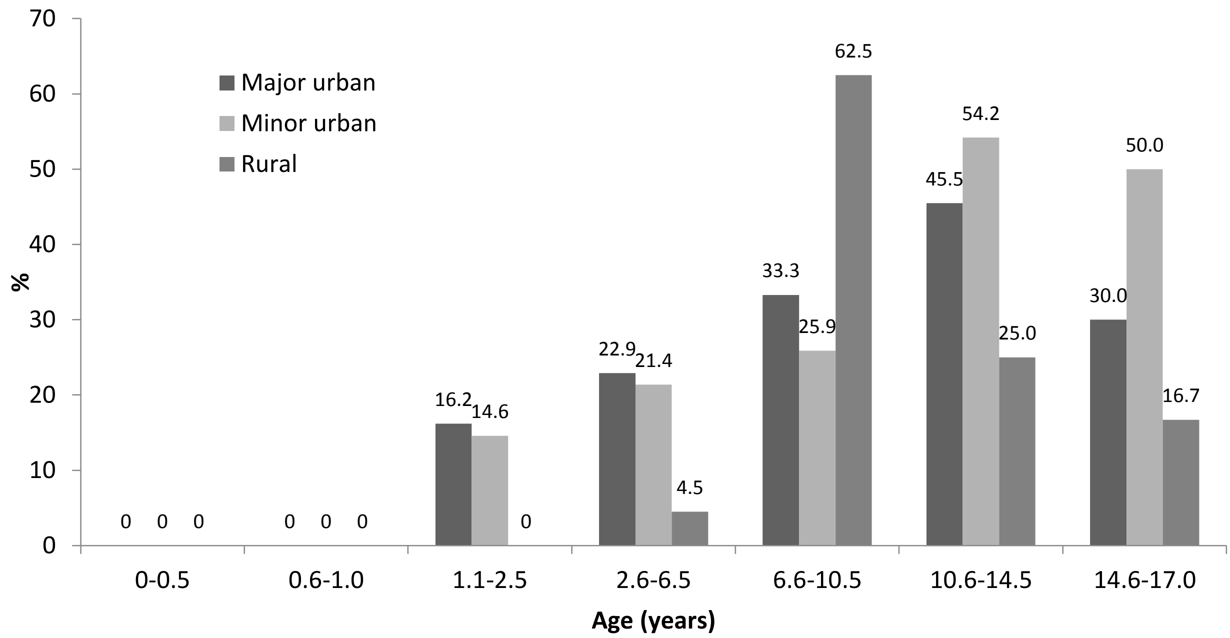


Figure 5.16. Crude prevalence rates of enamel hypoplasia by age

True prevalence rates of enamel hypoplasia have been calculated by erupted teeth present. A total of 309 out of 2700 teeth (TPR 11.4%) from major urban non-adults have displayed enamel defects. In minor urban contexts, 236 of 2460 teeth showed hypoplasia (TPR 9.6%). The total of 1087 teeth from rural sites yielded 49 teeth with enamel hypoplasia (TPR 4.5%) (Fig. 5.16). The rural true prevalence rate is significantly lower than those from urban contexts (X^2=43.66, p<0.001, d.f.=2). True prevalence rates of enamel hypoplasia by age category reveal a roughly different pattern to the one seen when comparing crude prevalence between the sites (Table 5.14).

Table 5.14. True prevalence rates of enamel hypoplasia by age

	Major urban			Minor urban			Rural			Total		
Age (yrs)	*n*	*%*	*N*	*n*	*%*	*N*	*n*	*%*	*N*	***n***	***%***	***N***
1.1-2.5	16	4.1	389	20	3.5	569	0	0	193	**36**	**3.1**	**1151**
2.6-6.5	41	7.5	550	38	4.8	790	2	0.8	251	**81**	**5.1**	**1591**
6.6-10.5	73	13.6	536	38	9.7	391	16	14.3	112	**127**	**12.2**	**1039**
10.6-14.5	152	17.3	878	94	18.2	517	22	7.0	315	**268**	**15.7**	**1710**
14.6-17.0	27	7.8	347	46	23.8	193	9	4.2	213	**82**	**10.9**	**753**
Non-adult	0	0	0	0	0	0	0	0	3	**0**	**0**	**3**
Total	**309**	**11.4**	**2700**	**236**	**9.6**	**2460**	**49**	**4.5**	**1087**	**594**	**9.5**	**6247**

% of cohort in individual age group by site type

Significantly lower true prevalence rates of enamel hypoplasia in the rural sample were found in 2.6-6.5-year olds (X^2=16.51, p<0.001, d.f.=2), 10.6-14.5-year olds (X^2=22.49, p<0.001, d.f.=2) and 14.6-17.0-year olds (X^2=46.31, p<0.001, d.f.=2). Although the major urban rate is also significantly lower than the minor urban rate in the adolescent age category (X^2=27.07, p<0.001, d.f.=1) (Fig. 5.17).

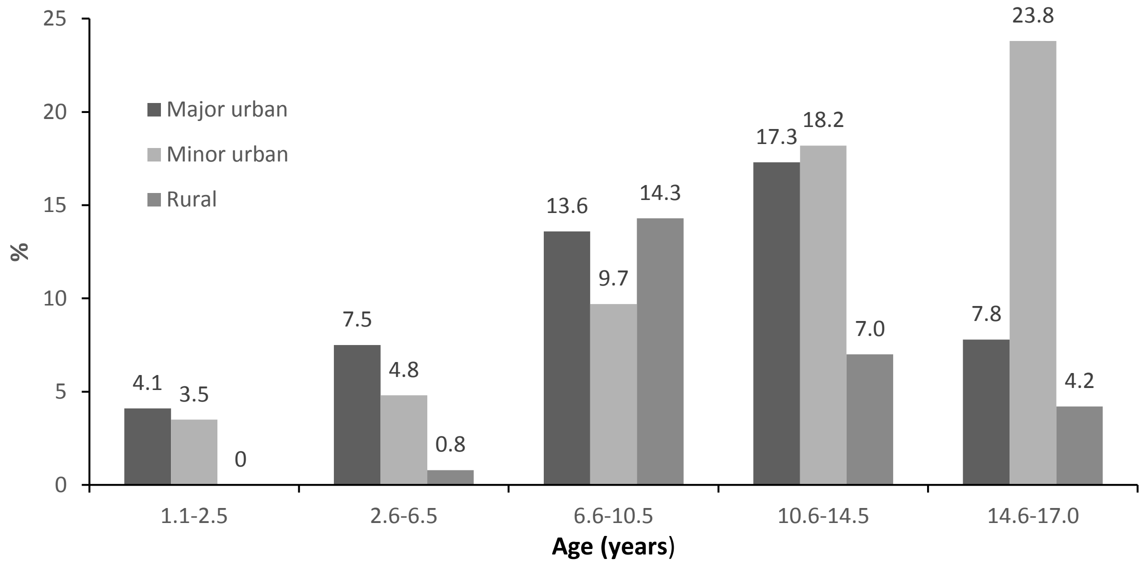


Figure 5.17. True prevalence rates of enamel hypoplasia by age

Table 5.15 lists the count and relative frequencies of teeth with enamel hypoplasia in erupted deciduous and permanent teeth separately. True prevalence rates for enamel hypoplasia in the rural sample are significantly lower than those from urban contexts in both the deciduous (X^2=13.39, p<0.005, d.f.=2) and permanent dentition (X^2=39.12, p<0.001, d.f.=2) (Fig. 5.18).

Table 5.15. True prevalence rates of enamel hypoplasia in erupted deciduous and permanent teeth

	Deciduous			**Permanent**		
	n	*%*	*N*	*n*	*%*	*N*
Major urban	26	2.4	1064	283	17.3	1636
Minor urban	20	1.5	1346	216	19.4	1114
Rural	0	0	481	49	8.1	606
Total	**46**	**1.6**	**2891**	**548**	**16.3**	**3356**

% of the cohort by site type; n=number of deciduous/permanent teeth with enamel hypoplasia; N=total of deciduous/permanent teeth

Table 5.16 presents the true prevalence rates of enamel hypoplasia in the permanent dentition only. In the anterior dentition (incisors and canines), true prevalence rates are almost similar in major urban and minor urban sites with 31.8% (n=206) and 31.3% (n=145) respectively. Rural rates (TPR 19.9%, n=46) are significantly lower than those in major urban (X^2=11.96, p<0.001, d.f.=1) and minor urban sites (X^2=10.04, p<0.005, d.f.=1). Hypoplastic defects have also been found on the posterior dentition (premolars and molars), with one case from a rural site (TPR 0.3%). However TPR 4.2% (n=41) of posterior teeth from major urban sites, and TPR 8.6% (n=55) from minor urban sites displayed hypoplasia. The distribution is statistically significant (X^2=37.16, p<0.001, d.f.=2) (Fig. 5.18).

Table 5.16. True prevalence rates of enamel hypoplasia in the erupted permanent dentition

	Anterior[1]			**Posterior**[1]		
	n	*%*	*N*	*n*	*%*	*N*
Major urban	206	31.8	647	41	4.2	978
Minor urban	145	31.3	464	55	8.6	640
Rural	46	19.9	231	1	0.3	368
Total	**397**	**29.6**	**1342**	**97**	**4.9**	**1986**

[1] minimum of two permanent teeth present per individual with at least two permanent teeth affected; % of cohort in individual age group by site type; n=number of anterior/posterior teeth with enamel hypoplasia; N=total of anterior/posterior teeth

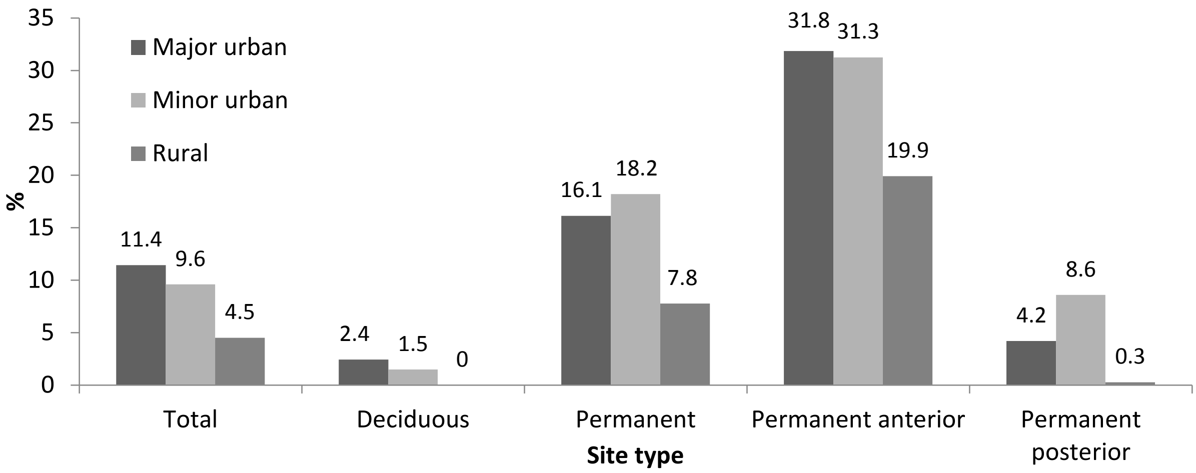


Figure 5.18. True prevalence rates of enamel hypoplasia in different categories of erupted teeth

5.3.4.4.2. Enamel hypoplasia and growth

Femoral diaphyseal lengths were plotted against dental age, comparing growth profiles of non-adults with and without enamel hypoplasia in Figure 5.19, with the individual measurements listed in A6.8 (in Appendix VI). Femoral diaphyseal lengths between non-adults with and without enamel hypoplasia differ significantly at the 99.5% level (KS=1.745, p=0.005). Individuals with enamel hypoplasia exhibit longer femoral diaphyses for the first ten years of life. Those without hypoplastic dental defects have longer femoral diaphyses aged 10 years and older.

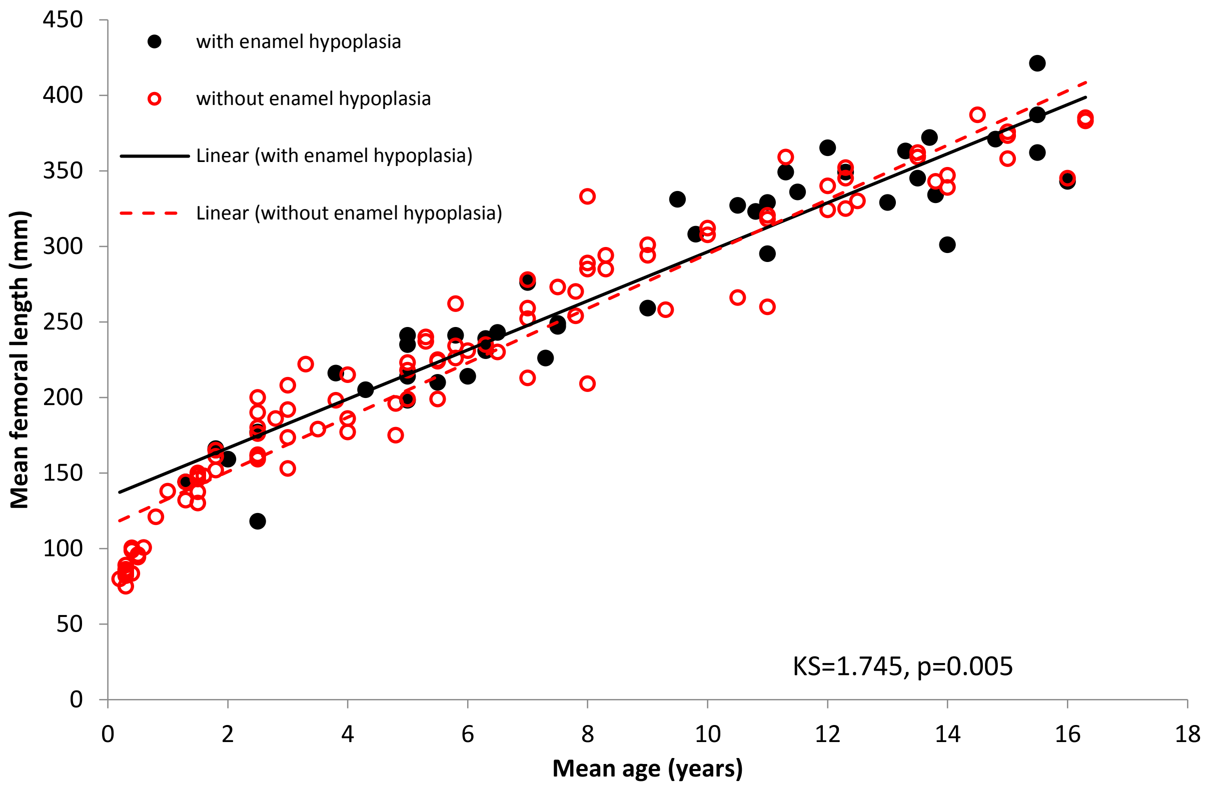


Figure 5.19. Femoral diaphyseal growth profiles of individuals with enamel hypoplasia

5.3.4.4.3. Non-specific infection

Several lesions have been classified as infections of non-specific origin. Endocranial lesions are considered as resulting from inflammation secondary to infection, as long as they are not linked with a systemic nutritional deficiency, trauma or tuberculosis (Lewis 2004; 2011). New bone formation, osteitis and osteomyelitis were also considered as indicative of non-specific infection, included in Table 5.12 and Figure 5.15. It is understood that this classification may be limited by the fact that new bone formation is also a result of haemorrhaging, rather than infection and can be masked or exacerbated by metabolic disease (Klaus 2014). The age of the individual, the location of the new bone formation, and any other existing lesions throughout the skeleton were taken into account. Individuals below the age of six months old were omitted from this part of analysis as the rapid growth within this age group may mimic sub-periosteal new bone formation.

5.3.4.4.4. Endocranial lesions

Table 5.17 presents the counts of endocranial lesions by age group and site type, with the true prevalence rates displayed in Figure 5.20. Overall 9.9% (n=47) of individuals with crania exhibited endocranial lesions. The highest rate of endocranial lesions was found in the minor urban cemeteries at TPR 15.9% (n=30), which is statistically significant (X^2=16.52, p<0.001, d.f.=2). It is of interest that lesions were found in older children and adolescents which are certain to be pathological in these age groups.

Table 5.17. True prevalence rates of endocranial lesions

	Major urban			Minor urban			Rural			Total		
Age (yrs)	*n*	*%*	*N*	*n*	*%*	*N*	*n*	*%*	*N*	***n***	***%***	***N***
0.6-1.0	0	0	4	3	15.8	19	0	0	9	**3**	**9.4**	**32**
1.1-2.5	4	13.5	37	11	20.4	54	3	13.0	23	**18**	**15.8**	**114**
2.6-6.5	0	0	48	8	14.0	57	3	13.6	22	**11**	**8.7**	**127**
6.6-10.5	2	6.1	33	5	21.7	23	1	14.3	7	**8**	**12.7**	**63**
10.6-14.5	0	0	41	1	4.4	23	2	11.8	17	**3**	**3.7**	**81**
14.6-17.0	1	4.6	22	2	25.0	8	1	7.7	13	**4**	**9.3**	**43**
Non-adult	0	0	11	0	0	5	0	0	1	**0**	**0**	**17**
Total	**7**	**3.6**	**196**	**30**	**15.9**	**189**	**10**	**10.9**	**92**	**47**	**9.9**	**477**

% of cohort in individual age group by site type

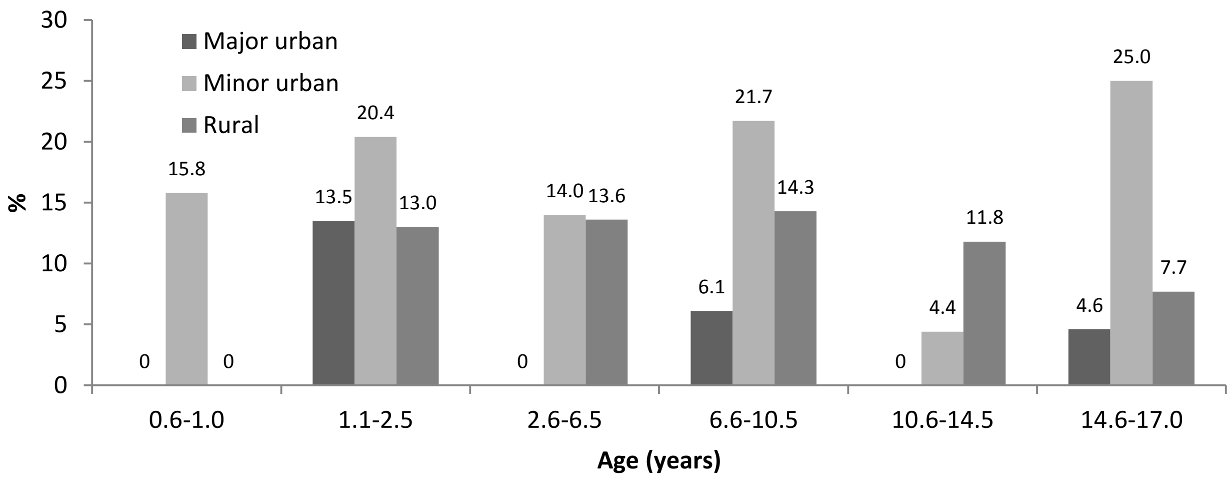


Figure 5.20. True prevalence rates of endocranial lesions by age

Types 1 to 4 were recorded, with type 3 (31.7%, n=19) being the most common, although the distribution is not significant (X^2=2.76) (Table 5.18). Lesions on the occipital bone were most frequent at 49.2% (n=32), whereas those on the temporal bone were the least frequently recorded (7.7%, n=5) (Table 5.18). The distribution of the locations of lesions is statistically significant (X^2=27.18, p<0.001, d.f.=3). Within the total sample, occipital lesions were recorded in TPR 6.1% (n=29) of individuals (Table 5.20). Endocranial lesions on the occipital bone were most frequent in all age groups, apart from 10.6-14.5-year olds, where lesions on the parietal bones were most common (TPR 2.5%, n=2) (Table 5.19, Fig. 5.21). The majority of lesions were active (55.3%, n=26), with 53.8% (n=13) of those in individuals younger than 2.5 years old (Table 5.20). Table 5.31 shows the average age-at-death for individuals with and without endocranial lesions, which are not significantly different in the three site types.

Table 5.18. Endocranial lesions by type and location

Type	**n**	**%**	**Location**	**n**	**%**
1	16	26.7	**Occipital**	29	46.8
2	13	21.7	**Parietal**	17	27.4
3	19	31.7	**Frontal**	11	17.7
4	12	20.0	**Temporal**	5	8.1
Total N	**60**		**N**	**62**	

% of total

Table 5.19. Location of endocranial lesions by age in the primary study sample

	Occipital		**Parietal**		**Frontal**		**Temporal**		**Total**
Age (yrs)	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	***N***
0.6-1.0	3	9.4	1	3.1	0	0	0	0	**32**
1.1-2.5	11	9.6	8	7.0	5	4.4	2	1.8	**114**
2.6-6.5	6	4.7	3	2.4	3	2.4	1	0.8	**127**
6.6-10.5	5	7.9	2	3.2	1	1.6	2	3.2	**63**
10.6-14.5	1	1.2	2	2.5	1	1.2	0	0	**81**
14.6-17.0	3	7.0	1	2.3	1	2.3	0	0	**43**
Total	**29**	**6.1**	**17**	**3.6**	**11**	**2.3**	**5**	**1.0**	**477**

% of total sample by age group

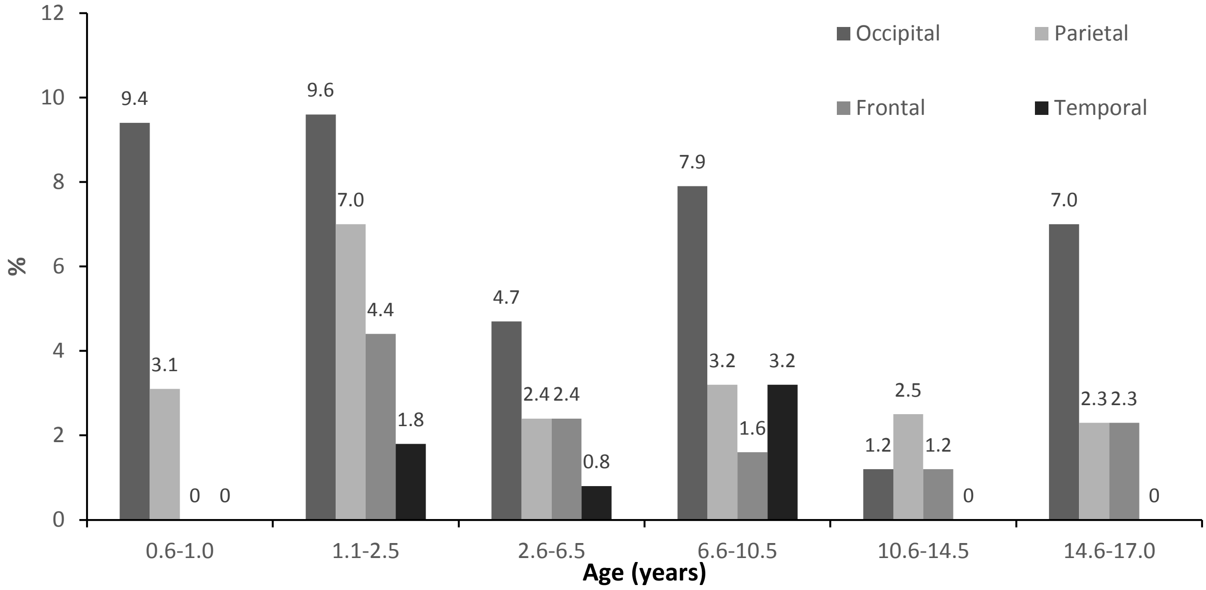


Figure 5.21. Distribution of endocranial lesions in each age category for the primary study sample combined

Table 5.20. Distribution of active endocranial lesions

	n	**%[1]**	**%[2] (N)**
0.6-1.0	1	3.8	33.3 (3)
1.1-2.5	13	50.0	72.2 (18)
2.6-6.5	5	19.3	45.5 (11)
6.6-10.5	3	11.5	37.5 (8)
10.6-14.5	2	7.7	66.7 (3)
14.6-17.0	2	7.7	50.0 (4)
Total	**26**	**100**	**55.3 (47)**

[1]% of total active lesions N=26; [2]% of the total of individuals with endocranial lesions by age group

5.3.4.4.5. New bone formation

New bone formation affected a total of 7.7% (n=37) of individuals with postcrania. The highest rate was reported in the major urban assemblage (CPR 9.9%, n=18) but the total rates of new bone formation do not differ between the site types (X^2=2.53) (Fig. 5.22). No significant distribution was found when comparing the crude prevalence rates of new bone formation by site across the individual age categories (Table 5.21). Mean ages-at-death of those with and without new bone formation did not differ statistically at the 99.9% level. However, in major urban non-adults those with new bone formation were on average 3.5 years older at death than those without. This difference is significant at the 99.8% level (KS=1.833, p=0.002) (Table 5.31).

Table 5.21. Crude prevalence rates of new bone formation

	Major urban			**Minor urban**			**Rural**			**Total**		
Age (yrs)	*n*	*%*	*N*	*n*	*%*	*N*	*n*	*%*	*N*	***n***	***%***	***N***
0.6-1.0	0	0	5	1	7.4	27	0	0	14	**1**	**2.2**	**46**
1.1-2.5	2	7.4	27	2	4.1	49	0	0	19	**4**	**4.2**	**95**
2.6-6.5	4	8.7	46	7	11.3	62	1	4.0	25	**12**	**9.0**	**133**
6.6-10.5	5	13.5	37	2	8.0	25	1	14.3	7	**8**	**11.6**	**69**
10.6-14.5	5	13.9	36	2	7.4	27	1	5.9	17	**8**	**10**	**80**
14.6-17.0	2	9.1	22	0	0	11	2	15.4	13r	**4**	**8.7**	**46**
Non-adult	0	0	9	0	0	3	0	0	0	**0**	**0**	**12**
Total	**18**	**9.9**	**182**	**14**	**6.9**	**204**	**5**	**5.3**	**95**	**37**	**7.7**	**481**

% of cohort in individual age group by site type; N= number of individuals with postcrania;

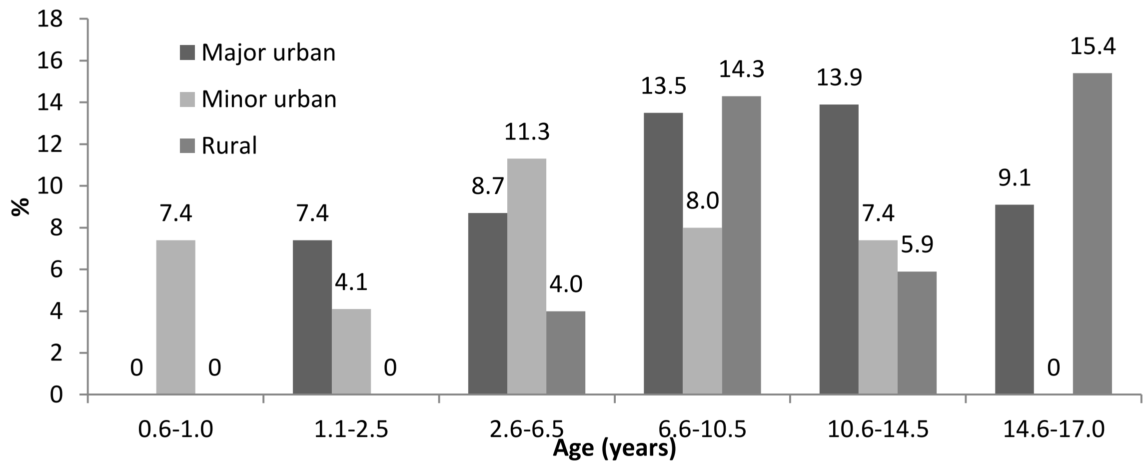


Figure 5.22. Crude prevalence rates of new bone formation by age

5.3.4.4.6. New bone formation and growth

Femoral diaphyseal lengths were plotted against dental age, comparing growth profiles of non-adults with and without evidence for periosteal new bone formation in Figure 5.23, with the individual measurements listed in A6.9 (in Appendix VI). The Kolmogorov-Smirnov test shows that there is no statistically significant difference in femoral growth between individuals with non-specific infection and those without (KS=1.045, p=0.225).

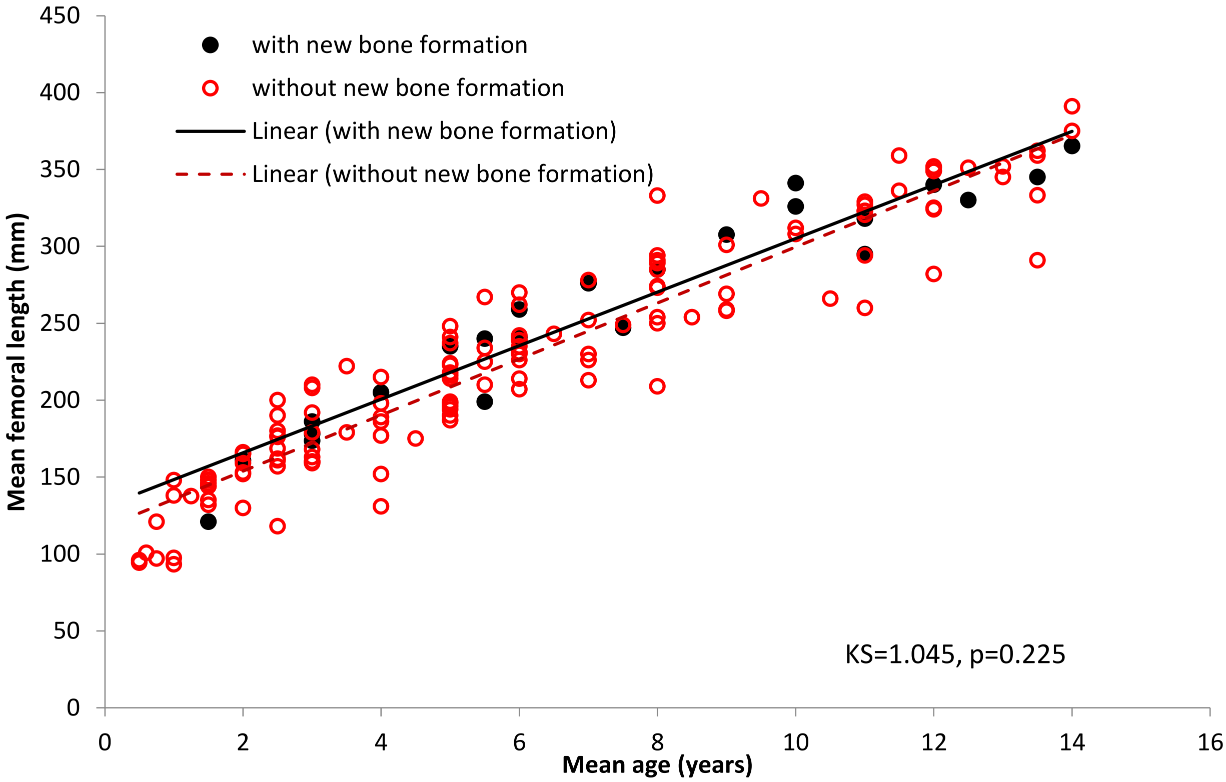


Figure 5.23. Femoral diaphyseal growth profiles of individuals with new bone formation

5.3.4.4.7. Association between stress indicators and infection

Yule's Q was calculated as a measure for the expression of a relationship between enamel hypoplasia, cribra orbitalia, endocranial lesions, and periosteal new bone formation, as infection and nutritional or environmental stress may be correlated (Lallo et al. 1977; Mensforth et al. 1978; Cook and Buikstra 1979; Lewis 2002b, 48; Slaus 2008). Endocranial lesions only have a weak relationship with enamel hypoplasia (Q=0.41), or cribra orbitalia (Q=0.40). Periosteal new bone formation shares a moderate relationship with both enamel hypoplasia (Q=0.51), and cribra orbitalia (Q=0.51). Endocranial lesions and new bone formation share virtually no relationship (Q=0.13).

5.3.4.5. Metabolic disease

5.3.4.5.1. Cribra orbitalia

The true prevalence rates for cribra orbitalia in individuals with at least one orbit are presented in Table 5.22. The highest rate for the total sample was recorded in the 2.6-6.5 year age group with TPR 40.2% (n=87) of individuals affected. Infants over six months of age, and perinatal individuals exhibited no hypertrophic lesions on the orbital roof. The distribution across the remaining age groups is statistically significant (X^2=39.71, p<0.001, d.f.=5). Within the 1.1-2.5 year age group, the rate is significantly higher in the rural sample (TPR 64.3%, n=9) than the urban samples (X^2 =15.28, p<0.001, d.f.=2) (Fig. 5.24).

Active lesions were more prevalent (77.0%, n=77) and there was a higher rate of active lesions in the rural cohort (X^2=10.28, p<0.01, d.f.=2) (Table 5.23). Within the individual age groups, the frequencies of active cribra orbitalia do not differ statistically (Fig. 5.25). Within the total sample, the highest rate of active lesions was found in 2.6-6.5-year olds at TPR 27.6% (n=24) (Table 5.23). The distribution of healing lesions by age is similar across the major and minor urban site types (Fig. 5.26). In rural settlements, only one 1.1-2.5-year old was recorded with healed lesions. In the urban site types, healing lesions were proportionately most frequent in adolescents. The 14.6-17.0 year age group also holds the highest frequency of healed lesions within the total sample at TPR 11.4% (n=4) (Table 5.24). In the total sample of 510 individuals with orbits, Grade 3 lesions are the most frequent (TPR 11.2%, n=57), see Table 5.25. This distribution is statistically significant (X^2=25.83, p<0.001, d.f.=2). There is no difference in the severity of lesions between different settlement contexts: for Grade 3 X^2=1.43, for Grade 4 X^2=2.32 and for Grade 5 X^2=4.08 (Fig. 5.27).

Mean age-at-death in individuals with cribra orbitalia are significantly higher, compared to individuals without orbital lesions across all three site types (Table 5.31). In major urban contexts, individuals with cribra orbitalia are on average four years older at death with 8.7±4.6 years, compared to those without the lesions with 4.7±5.2 years (KS=2.436, p<0.001). In minor urban sites, individuals with cribra orbitalia are on average 3.8 years older (7.1±4.0 years) than non-adults without cribra orbitalia (3.3±4.3 years). This difference is significant with KS=2.979 (p<0.001). Rural non-adults with cribra orbitalia are 3.1 years older at death with 6.8±5.5 years, compared to individuals without cribra orbitalia at 3.7±5.3 years, and the distribution is significant (KS=2.639, p<0.001).

Table 5.22. True prevalence rates of cribra orbitalia by age

	Major urban			**Minor urban**			**Rural**			**Total**		
Age (yrs)	*n*	*%*	*N*	*n*	*%*	*N*	*n*	*%*	*N*	***n***	***%***	***N***
< 37 wks	0	0	17	0	0	7	0	0	8	**0**	**0**	**32**
38-40 wks	0	0	37	0	0	30	0	0	11	**0**	**0**	**78**
0-0.5	0	0	27	0	0	16	1	4.6	22	**1**	**1.5**	**65**
0.6-1.0	0	0	3	0	0	10	0	0	4	**0**	**0**	**17**
1.1-2.5	4	13.3	30	6	16.2	37	9	64.3	14	**19**	**23.5**	**81**
2.6-6.5	10	31.3	32	19	45.2	42	6	46.2	13	**35**	**40.2**	**87**
6.6-10.5	5	20.8	24	7	38.9	18	4	66.7	6	**16**	**33.3**	**48**
10.6-14.5	10	33.3	30	6	30.0	20	3	25.0	12	**19**	**30.7**	**62**
14.6-17.0	6	33.3	18	2	33.3	6	5	45.5	11	**13**	**37.1**	**35**
Non-adult	1	20.0	5	0	0	0	0	0	0	**1**	**20.0**	**5**
Total	**36**	**16.1**	**223**	**40**	**21.5**	**186**	**28**	**27.7**	**101**	**104**	**20.4**	**510**

% of cohort in individual age group by site type

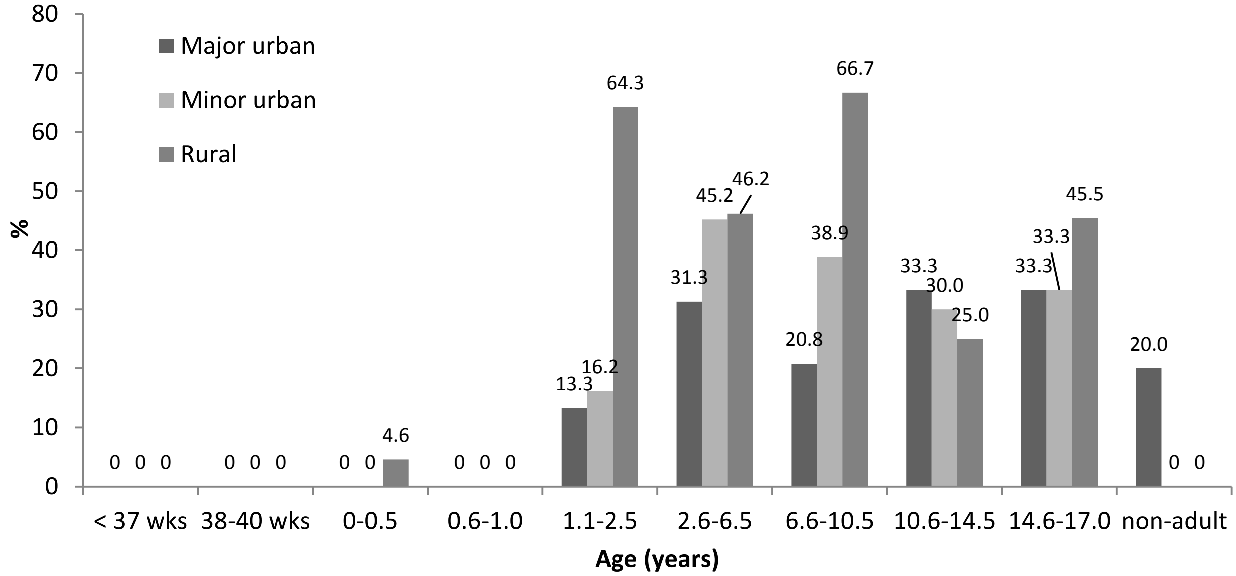


Figure 5.24. True prevalence rates of cribra orbitalia by age

Table 5.23. True prevalence rates of active cribra orbitalia by age

	Major urban			**Minor urban**			**Rural**			**Total**		
Age (yrs)	*n*	*%*	*N*	*n*	*%*	*N*	*n*	*%*	*N*	***n***	***%***	***N***
< 37 wks	0	0	17	0	0	7	0	0	8	**0**	**0**	**32**
38-40 wks	0	0	37	0	0	30	0	0	11	**0**	**0**	**78**
0-0.5	0	0	27	0	0	16	1	4.6	22	**1**	**1.5**	**65**
0.6-1.0	0	0	3	0	0	10	0	0	4	**0**	**0**	**17**
1.1-2.5	3	10.0	30	6	16.2	37	7	50.0	14	**16**	**19.8**	**81**
2.6-6.5	6	18.8	32	13	31.0	42	5	38.5	13	**24**	**27.6**	**87**
6.6-10.5	4	16.7	24	5	27.8	18	4	66.7	6	**13**	**27.1**	**48**
10.6-14.5	7	23.3	30	4	20.0	20	3	25.0	12	**14**	**22.6**	**62**
14.6-17.0	3	16.7	18	1	16.7	6	5	45.5	11	**9**	**25.7**	**35**
Non-adult	1	20.0	5	0	0	0	0	0	0	**1**	**20.0**	**5**
Total	**24**	**10.8**	**223**	**29**	**15.6**	**186**	**25**	**24.8**	**101**	**78**	**15.3**	**510**

% of cohort in individual age group by site type

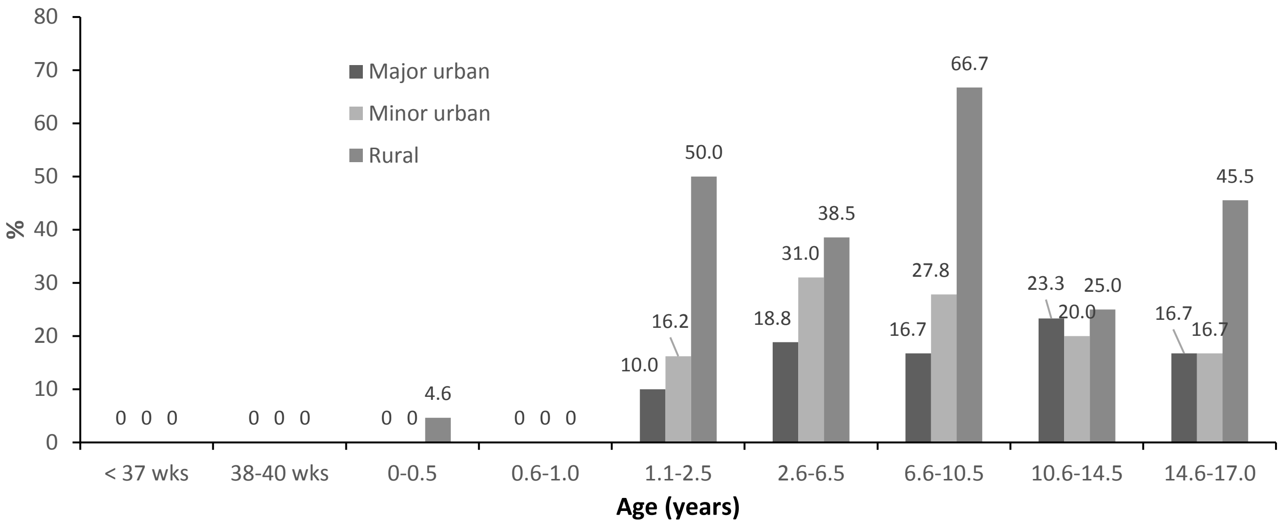


Figure 5.25. True prevalence rates of active cribra orbitalia by age

Table 5.24. True prevalence rates of healing cribra orbitalia by age

	Major urban			**Minor urban**			**Rural**			**Total**		
Age (yrs)	*n*	*%*	*N*	*n*	*%*	*N*	*n*	*%*	*N*	***n***	***%***	***N***
< 37 wks	0	0	17	0	0	7	0	0	8	**0**	**0**	**32**
38-40 wks	0	0	37	0	0	30	0	0	11	**0**	**0**	**78**
0-0.5	0	0	27	0	0	16	0	0	22	**0**	**0**	**65**
0.6-1.0	0	0	3	0	0	10	0	0	4	**0**	**0**	**17**
1.1-2.5	1	3.3	30	0	0	37	1	7.1	14	**2**	**2.5**	**81**
2.6-6.5	4	12.5	32	5	11.9	42	0	0	13	**9**	**10.3**	**87**
6.6-10.5	1	4.2	24	2	11.1	18	0	0	6	**3**	**6.3**	**48**
10.6-14.5	3	10.0	30	2	10.0	20	0	0	12	**5**	**8.1**	**62**
14.6-17.0	3	16.7	18	1	16.7	6	0	0	11	**4**	**11.4**	**35**
Non-adult	0	0	5	0	0	0	0	0	0	**0**	**0**	**5**
Total	**12**	**5.4**	**223**	**10**	**5.4**	**186**	**1**	**0.9**	**101**	**23**	**4.5**	**510**

% of cohort in individual age group by site type

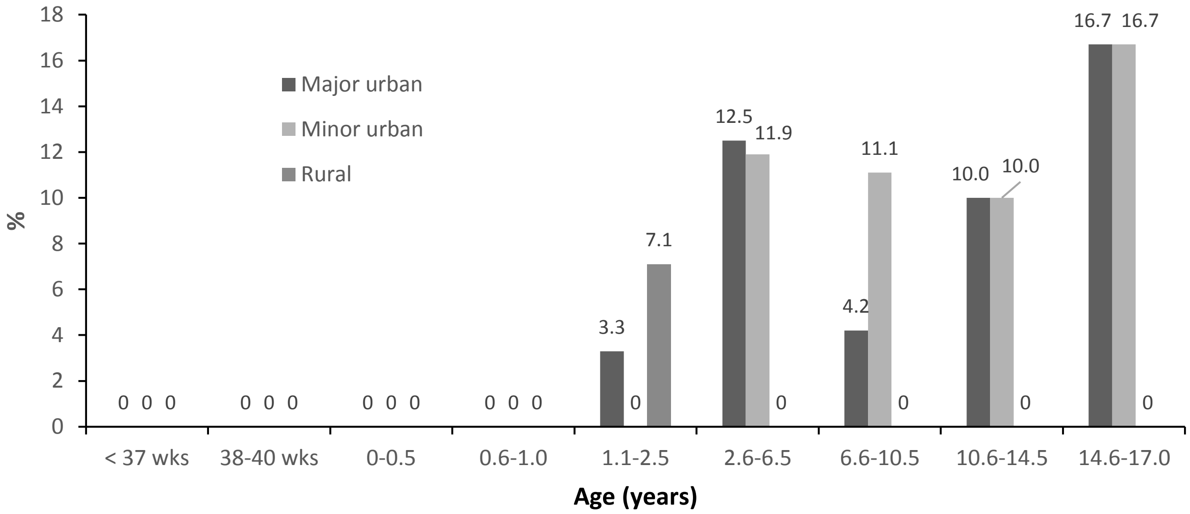


Figure 5.26. True prevalence rates of healing cribra orbitalia by age

Table 5.25. True prevalence rates of the severity of cribrotic lesions

	Major urban (N=223)		**Minor urban (N=186)**		**Rural (N=101)**		**Total (N=510)**	
	n	*%*	*n*	*%*	*n*	*%*	***n***	***%***
Grade 3	21	9.4	22	11.8	14	13.9	**57**	**11.2**
Grade 4	12	5.4	11	5.9	10	9.9	**33**	**31.1**
Grade 5	3	1.4	8	4.3	5	4.9	**16**	**15.1**
Total	**36**		**41**		**29**		**106**	

% of cohort by site type

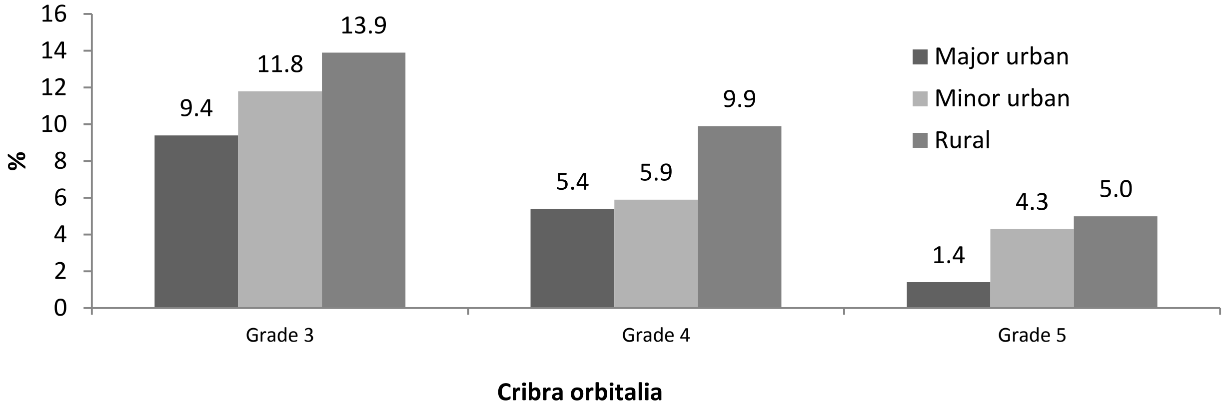


Figure 5.27. True prevalence rates of cribra orbitalia Grades 3-5

5.3.4.5.2. Cribra orbitalia and growth

Femoral diaphyseal measurements were plotted against dental age in Figure 5.28, comparing femoral growth in individuals with cribra orbitalia to those without marrow hypertrophy on the orbital roof. Individual femoral lengths are tabulated in A6.10 in Appendix VI. The growth profiles of non-adults with, as opposed to without cribra orbitalia do not differ statistically (KS=1.248, p=0.89).

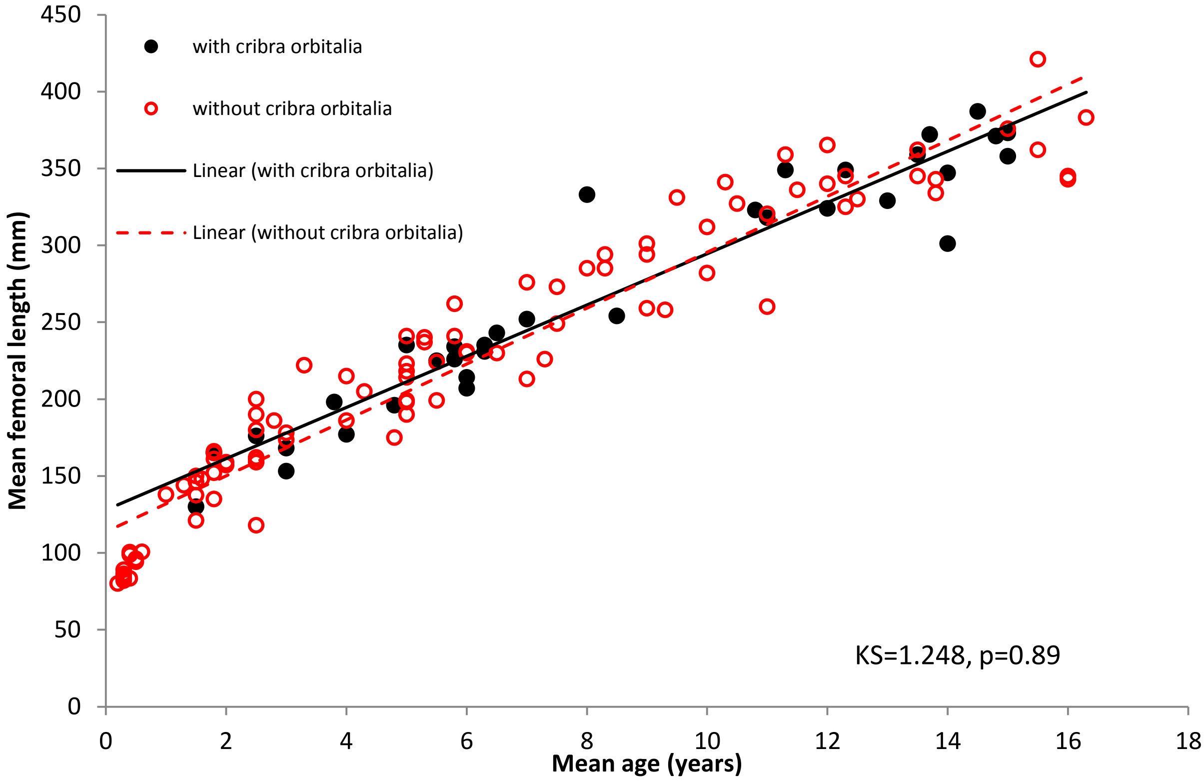


Figure 5.28. Femoral diaphyseal growth profiles of individuals with cribra orbitalia

5.3.4.5.3. Vitamin C and D deficiencies

Scurvy and rickets were distinguished whenever possible. However, co-morbidity is common, and lesions may appear similar which prevented a clear distinction of one from the other in some cases (Brickley and Ives 2008, 113-114). The highest crude prevalence rate for scurvy and rickets combined was recorded in the rural cohort (CPR 9.4%, n=19), compared to the major urban (CPR 6.4%, n=24) and the minor urban sites (CPR 6.1%, n=20), although the distribution is not significant (X^2=2.35) (Table 5.26). The highest rate of vitamin C and D deficiencies for the overall sample was found in infants up to six months old (CPR 11.3%, n=15) (Fig. 5.29). However, the widespread new bone formation seen in infants up to 6-months old interferes with a diagnosis of metabolic disease, especially scorbutic lesions, and these individuals have been omitted from further analysis (see section 7.1. on the limitations of the study and an appraisal of scurvy in neonatal remains).

Table 5.26. Crude prevalence rates of vitamin C and D deficiencies by age

	Major urban			**Minor urban**			**Rural**			**Total**		
Age (yrs)	*n*	*%*	*N*	*n*	*%*	*N*	*n*	*%*	*N*	***n***	***%***	***N***
< 37 wks	2	10.0	20	2	16.7	12	1	6.7	15	**5**	**10.6**	**47**
38-40 wks	8	13.1	61	4	7.4	54	1	3.9	26	**13**	**9.2**	**141**
0-0.5	5	9.6	52	6	16.7	36	4	8.9	45	**15**	**11.3**	**133**
0.6-1.0	1	16.7	6	1	3.6	28	2	13.3	15	**4**	**8.2**	**49**
1.1-2.5	3	7.5	40	4	7.1	56	6	25.0	24	**13**	**10.8**	**120**
2.6-6.5	3	5.0	60	2	3.0	67	2	6.5	31	**7**	**4.4**	**158**
6.6-10.5	0	0	44	1	3.6	28	1	9.1	11	**2**	**2.4**	**83**
10.6-14.5	0	0	47	0	0	28	2	10	20	**2**	**2.1**	**95**
14.6-17.0	2	7.2	28	0	0	11	0	0	14	**2**	**3.8**	**53**
Non-adult	0	0	20	0	0	7	0	0	1	**0**	**0**	**28**
Total	**24**	**6.4**	**378**	**20**	**6.1**	**327**	**19**	**9.4**	**202**	**63**	**7.0**	**907**

% of cohort in individual age group by site type

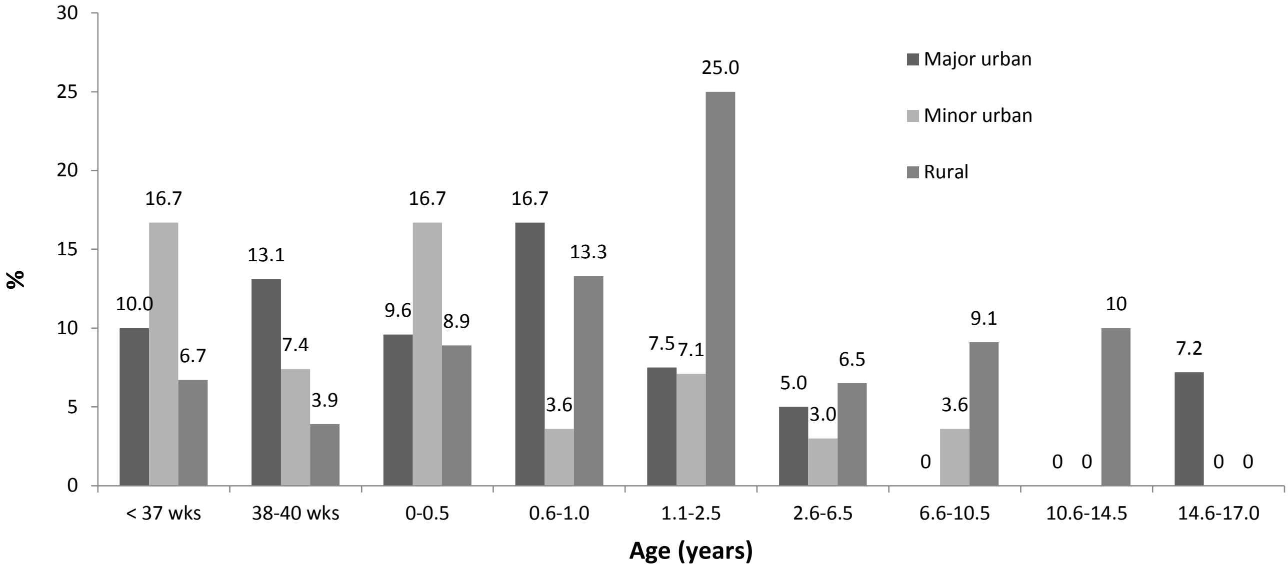


Figure 5.29. Crude prevalence rates of rickets and scurvy combined by age

The distribution of rickets between the sites types is not significant (X^2=0.49). Scurvy is statistically more frequent in rural children compared to those from urban sites (X^2=13.82, p<0.001, d.f.=2). Co-morbidity was only established in two 1.1-2.5-year olds from a minor urban and a rural site, and this sample is too small to warrant statistical analysis (Table 5.27).

Table 5.27. Comparison of the prevalence of rickets and scurvy across the site types

	Vitamin D deficiency			Vitamin C deficiency			Vitamin C and D deficiency		
	n	*%*	*N*	*n*	*%*	*N*	*n*	*%*	*N*
Major urban	6	2.4	245	3	1.2	245	0	0	245
Minor urban	5	2.2	225	2	0.9	225	1	0.4	225
Rural	4	3.4	116	8	6.9	116	1	0.9	116
Total	**15**	**2.6**	**586**	**13**	**2.2**	**586**	**2**	**0.3**	**586**

% of cohort by site type

For the total sample, the highest frequency of rickets was found in infants aged over six months old at CPR 8.2% (n=4). There is a trend for rickets to affect non-adults mostly below 2.5 years old (X^2=14.75, p<0.05, d.f.=5). The prevalence of rachitic lesions in affected individuals by age group does not differ statistically between the site types, see Table 5.28. Interestingly, the frequency of rachitic lesions in major urban and rural non-adults aged 0.6-1.0 and 1.1-2.5 years old are similar (Fig. 5.30). For the total sample, scorbutic lesions were most frequent in 1.1-2.5-year olds (CPR 3.3%, n=4), although the distribution across the age groups is not significant (X^2=4.51) (Table 5.29). In 1.1-2.5-year olds, scurvy is statistically more prevalent in rural children (CPR 12.5%, n=3; X^2=7.47, p<0.01, d.f.=2). Scurvy is also higher in rural non-adults aged 10.6-14.5 years old (CPR 10.0%, n=2), where no cases have been recorded in urban cemeteries. However the distribution is not significant but merely a trend (X^2=7.25) (Fig. 5.31).

Table 5.28. Crude prevalence rates of vitamin D deficiency by age

	Major urban			Minor urban			Rural			Total		
Age (yrs)	*n*	*%*	*N*	*n*	*%*	*N*	*n*	*%*	*N*	***n***	***%***	***N***
0.6-1.0	1	16.7	6	1	3.6	28	2	13.3	15	**4**	**8.2**	**49**
1.1-2.5	3	7.5	40	2	3.6	56	2	8.3	24	**7**	**5.8**	**120**
2.6-6.5	1	1.7	60	1	1.5	67	0	0	31	**2**	**1.3**	**158**
6.6-10.5	0	0	44	1	3.6	28	0	0	11	**1**	**1.2**	**83**
10.6-14.5	0	0	47	0	0	28	0	0	20	**0**	**0**	**95**
14.6-17.0	1	3.6	28	0	0	11	0	0	14	**1**	**1.9**	**53**
Non-adult	0	0	20	0	0	7	0	0	1	**0**	**0**	**28**
Total	**6**	**2.4**	**245**	**5**	**2.2**	**225**	**4**	**3.4**	**116**	**15**	**2.6**	**586**

% of cohort in individual age group by site type

Figure 5.30. Crude prevalence rates of rickets by age

Table 5.29. Crude prevalence rates of vitamin C deficiency by age

	Major urban			**Minor urban**			**Rural**			**Total**		
Age (yrs)	*n*	*%*	*N*	*n*	*%*	*N*	*n*	*%*	*N*	***n***	***%***	***N***
0.6-1.0	0	0	6	0	0	28	0	0	15	**0**	**0**	**49**
1.1-2.5	0	0	40	1	1.8	56	3	12.5	24	**4**	**3.3**	**120**
2.6-6.5	2	3.3	60	1	1.5	67	2	6.5	31	**5**	**3.2**	**158**
6.6-10.5	0	0	44	0	0	28	1	9.1	11	**1**	**1.2**	**83**
10.6-14.5	0	0	47	0	0	28	2	10	20	**2**	**2.1**	**95**
14.6-17.0	1	3.6	28	0	0	11	0	0	14	**1**	**1.9**	**53**
Non-adult	0	0	20	0	0	7	0	0	1	**0**	**0**	**28**
Total	**3**	**1.2**	**245**	**2**	**0.9**	**225**	**8**	**6.9**	**116**	**13**	**2.2**	**586**

% of cohort in individual age group by site type

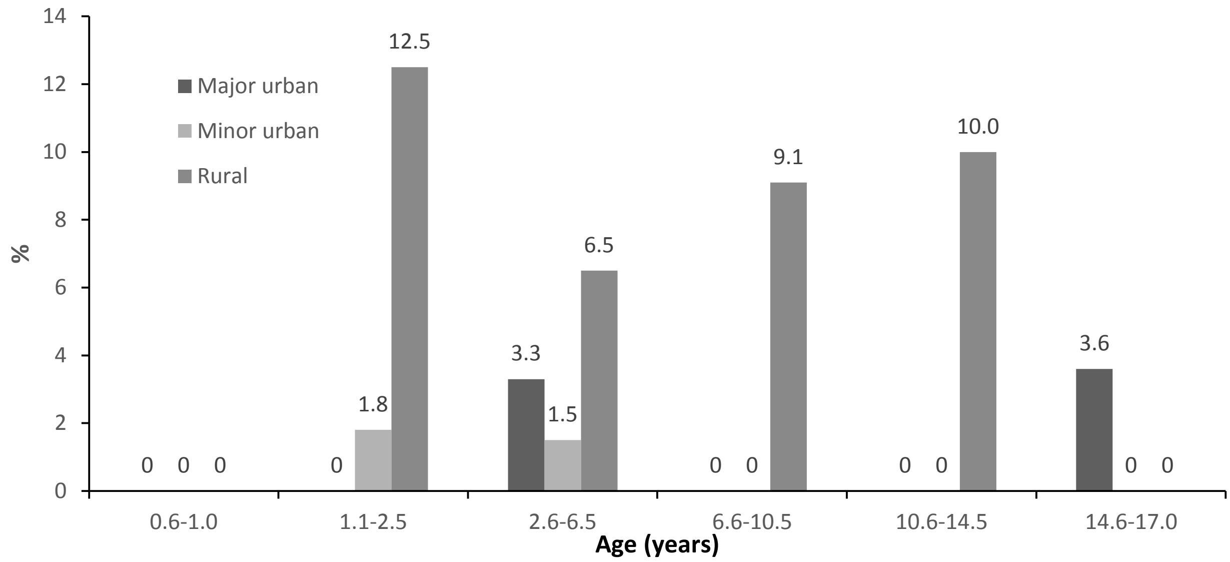


Figure 5.31. Crude prevalence rates of scurvy by age

Clear evidence for healed rickets and scurvy was only established in six cases. A scorbutic 2.6-6.5-year old from Kingsholm (skeleton 223) showed smoothing and remodelling of cranio-facial lesions, and similar findings were recorded in a 10.6-14.5-year old from Cannington (skeleton H1) and a 14.6-17.0-year old from Bath Gate, Cirencester (skeleton 63). Residual rickets was diagnosed in a 2.6-6.5-year old from Colchester (skeleton 123) with bending of the lower limbs, and healing lesions were found in a 2.6-6.5-year old from Great Casterton (skeleton 2092), and in a 6.6-10.5-year old at Queensford Farm/Mill (skeleton Que1982 47/228).

The average age-at-death in individuals with evidence for metabolic disease is lower than in individuals without skeletal indicators of metabolic disturbance in all three site types. However, the differences are not significant at the $p<0.001$ level (Table 5.31).

5.3.4.5.4. Metabolic disease and growth

Femoral diaphyseal lengths were plotted against dental age, comparing growth profiles of non-adults with and without evidence for metabolic disease in Figure 5.32 with the individual measurements listed in A6.11 (in Appendix VI). Applying the Kolmogorov-Smirnov test shows that there is no statistically significant difference in femoral lengths between individuals with metabolic disease and those without (KS=1.238, p=0.093). This result is probably influenced by the small sample size of individuals with metabolic disease and femoral measurements (n=10).

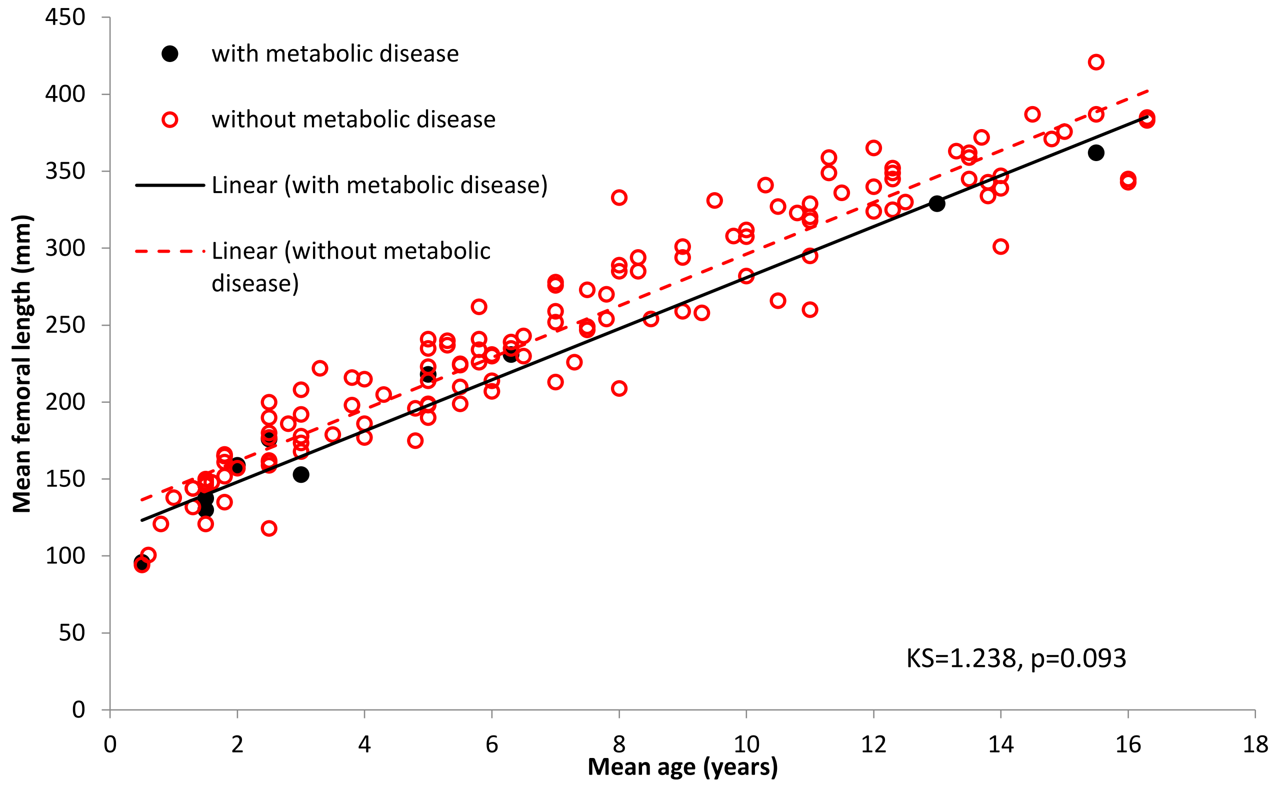


Figure 5.32. Femoral diaphyseal growth profiles of individuals with metabolic disease

5.3.4.5.5. Porotic hyperostosis

The occurrence of porotic hyperostosis without evidence for rickets or scurvy may be interpreted as an anaemic response to either dietary deficiencies, genetic causes, or as a haemorrhaging or inflammatory process (Stuart-Macadam 1987; Ortner 2003, 89; Walker et al. 2009; Roberts and Manchester 2010, 230). Similar to the approach taken for the recording of cribra orbitalia, lesions of Grades 1 and 2 were excluded to prevent over-recording. The presentation of prevalence rates excludes individuals without crania (TPR). The highest rate of porotic hyperostosis was found in the 1.1-2.5 year age category (TPR 7.8%, n=8) for individuals from all sites, which is statistically significant (X^2=27.1, p<0.001, d.f.=8) (Table 5.30). Marrow expansion on the cranium occurred at a higher rate in the rural sample, although the result is only significant at the 99% level (TPR 6.2%, n=8; X^2=9.84, p<0.01, d.f.=2). Overall only few non-adults were recorded with this lesions, and meaningful testing of the distributions by age between the site types was prevented due to small sample sizes. In 1.1-2.5-year olds, the distribution of porotic hyperostosis is not significant (X^2=5.79) (Fig. 5.33).

Table 5.30. True prevalence rates of porotic hyperostosis by age

	Major urban			**Minor urban**			**Rural**			**Total**		
Age (yrs)	*n*	*%*	*N*	*n*	*%*	*N*	*n*	*%*	*N*	***n***	***%***	***N***
< 37 wks	0	0	15	0	0	4	0	0	8	**0**	**0**	**27**
38-40 wks	0	0	36	0	0	33	0	0	12	**0**	**0**	**81**
0-0.5	0	0	39	0	0	18	1	3.5	29	**1**	**1.2**	**86**
0.6-1.0	0	0	3	1	5.6	18	0	0	8	**1**	**3.5**	**29**
1.1-2.5	2	5.7	35	2	4.0	50	4	22.2	18	**8**	**7.8**	**103**
2.6-6.5	0	0	45	0	0	54	0	0	20	**0**	**0**	**119**
6.6-10.5	0	0	33	0	0	22	0	0	6	**0**	**0**	**61**
10.6-14.5	1	2.4	41	0	0	23	0	0	15	**1**	**1.3**	**79**
14.6-17.0	0	0	20	0	0	8	2	15.4	13	**2**	**4.9**	**41**
Non-adult	1	9.1	11	0	0	5	1	100	1	**2**	**11.8**	**17**
Total	**4**	**1.4**	**278**	**3**	**2.8**	**235**	**8**	**6.2**	**130**	**15**	**2.3**	**643**

% of cohort in individual age group by site type

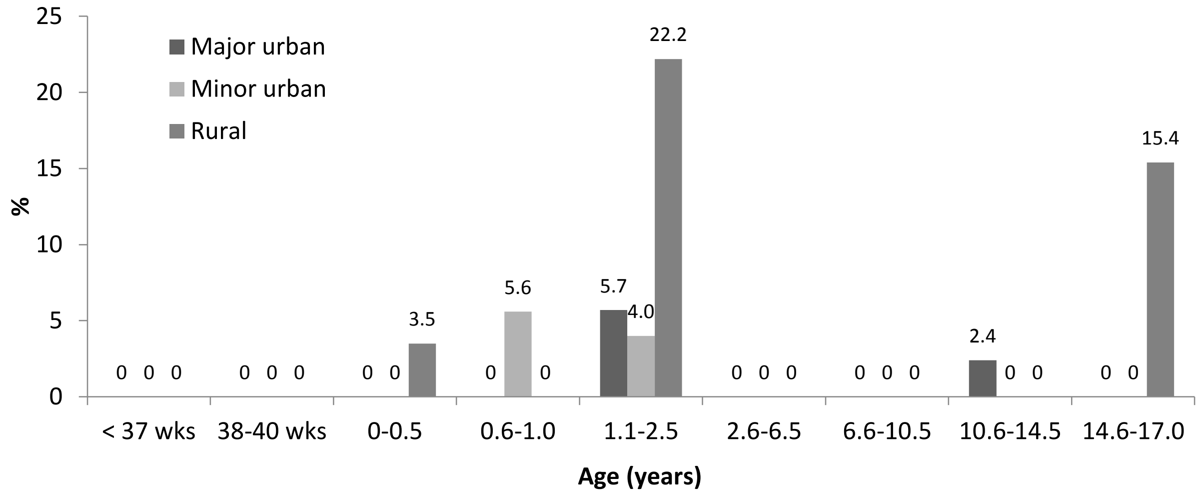


Figure 5.33. True prevalence rates of porotic hyperostosis by age

Table 5.31. Mean ages-at-death in individuals with and without pathology

	Major urban					
	with	*S.D.*	*without*	*S.D.*	*difference*	*KS test*
Enamel hypoplasia	9.2	4.1	6.4	5.0	2.8	1.878, p=0.002
New bone formation	8.3	4.6	4.9	5.3	3.5	1.833, p=0.002
Endocranial lesions	5.8	5.3	5.4	5.3	0.4	0.866, p=0.441
Cribra orbitalia	8.7	4.6	4.7	5.2	**4.0**	**2.436, p<0.001**
Metabolic disease	4.4	5.0	7.7	4.8	3.3	1.749, p=0.004
	Minor urban					
	with	*S.D.*	*without*	*S.D.*	*difference*	*KS test*
Enamel hypoplasia	8.5	4.6	4.6	4.0	**3.9**	**2.200, p<0.001**
New bone formation	6.3	4.7	3.7	4.5	2.7	1.459, p=0.028
Endocranial lesions	4.0	4.1	4.2	4.6	0.3	1.475, p=0.026
Cribra orbitalia	7.1	4.0	3.3	4.3	**3.8**	**2.979, p<0.001**
Metabolic disease	2.4	2.4	5.5	4.5	3.2	1.822, p=0.003
	Rural					
	with	*S.D.*	*without*	*S.D.*	*difference*	*KS test*
Enamel hypoplasia	11.0	3.2	5.6	5.4	**5.5**	**2.032, p=0.001**
New bone formation	6.7	4.5	4.0	5.4	2.6	1.603, p=0.012
Endocranial lesions	4.8	5.5	5.0	5.7	0.2	1.029, p=0.24
Cribra orbitalia	6.8	5.5	3.7	5.3	**3.1**	**2.639, p<0.001**
Metabolic disease	4.8	5.2	6.7	5.5	1.9	1.230, p=0.097

Minimum significance p<0.001

5.3.4.5.6. Association between stress indicators and metabolic disease

Metabolic disease and nutritional stress and infection may be correlated, and individuals that suffered from rickets and scurvy may also have been affected by cribra orbitalia or enamel hypoplasia (Mensforth et al. 1978). Yule's Q was used as a measure of association for metabolic disease, and nutritional and environmental stress expressed as enamel defects. It was also calculated to evaluate the relationship between metabolic disease and cribra orbitalia as an expression of an anaemic response and nutritional stress. The association between metabolic disease and enamel hypoplasia in this Romano-British sample is only weak (Q=0.44). A similar finding was made for the relationship of metabolic disease and cribra orbitalia (Q=0.42).

5.3.4.6. Thalassaemia

Skeletal lesions that may be indicative of thalassaemia have been recorded in three individuals exclusively from major urban contexts who have not been reported previously with genetic anaemia. One stems from the burial ground at Butt Road in Colchester, and two from the cemetery site at 35 Kingsholm Road in Gloucester. These are presented below as case studies with differential diagnoses.

5.3.4.6.1. Skeleton 145, Butt Road, Colchester

Skeleton 145, a young child at Butt Road, Colchester has a mean dental age of 1-1.5 years. The burial consists of the trunk, upper and lower limbs, and the skull is represented by the mandible only. The individual displayed several different conditions, including trauma, and probable thalassaemia and vitamin D deficiency. Enlargement of the sternal rib ends and epiphyseal fraying in the upper limbs suggest vitamin D deficiency, but can also be found in thalassaemia. There is a fracture callus on the right distal radius, with extensive new bone formation, again this may be attributed to the vitamin D deficiency, but a differential diagnosis also suggests that the fracture may be the result of loss in bone mineral density secondary to thalassaemia. Fractures are common in modern clinical cases in transfusion-dependent patients with rates of 12.1% in thalassaemia intermedia (Vogiatzi et al. 2006). Finsterbush et al. (1985) reported rates of almost 50%, and Ruggiero and DeSanctis (1998) found 19.7% of thalassaemia patients affected by fractures, which were found to be more common in children and adolescents. The prevalence of fractures in modern thalassaemia patients steadily declined as transfusion and chelation therapies became more readily available (Vogiatzi et al. 2006), which suggests that fracture rates in thalassaemic individuals in the past may have been higher.

The ribs are marked by localised thickening of the shafts. Macroscopically, the expanded foci do not appear porous, or as healed sub-periosteal new bone deposits, but rather as localised masses on top of the original cortical bone (i.e. costal osteomas) (Figs. 5.34 and 5.37). Radiographs of the ribs show a radio-opaque appearance of the foci of lamellar bone which are deposited on the original cortex (Figs. 5.35 and 5.36). The long bones exhibit enlarged trabecular structure and cortical thinning suggestive of osteopenia, some localised pitting of the cortex and thickening towards the epiphyseal ends is evident (Figs. 5.34 and 5.35). The cranial vault is absent and cannot be assessed for marrow expansion. Overall, the skeleton does not display the gross extreme skeletal alterations described by Lagia et al. (2007) and Lewis (2012) for β-thalassaemia intermedia. However, there is a wide phenotypic variation in the clinical expression of β-thalassaemia (Weatherall and Clegg 1999), which may account for the more contained skeletal changes observed in skeleton 145.

a,  b, 

Figure 5.34. Possible thalassaemia at Butt Road I. a, right ribs superiorly with localised cortical thickening; b, radii and ulnae appear thickened with porosity of the cortex, enlarged and splayed epiphyseal ends, right radius with fracture. From Butt Road, Colchester, skeleton 145. (with permission from Colchester and Ipswich Museums)

a,  b, 

Figure 5.35. Possible thalassaemia at Butt Road II. a, ribs superiorly with radio-opaque appearance of the localised masses deposited on the original cortex; b, radii, fracture callus on the right distal radius (left), note cortical thinning at epiphyseal ends and enlarged trabecular structure. From Butt Road, Colchester, skeleton 145. (with permission from Colchester and Ipswich Museums)

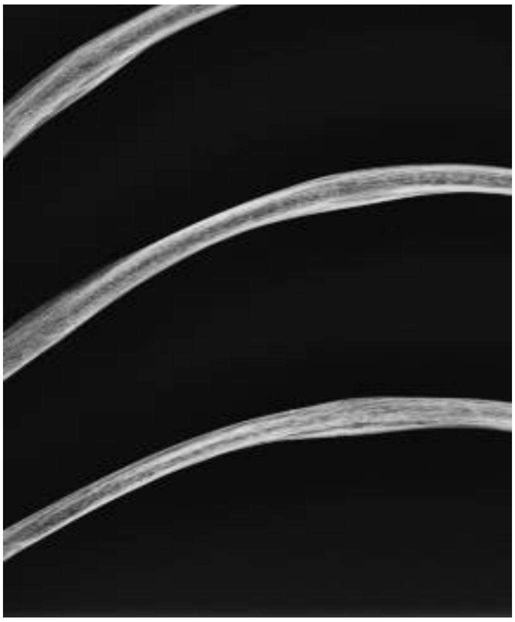
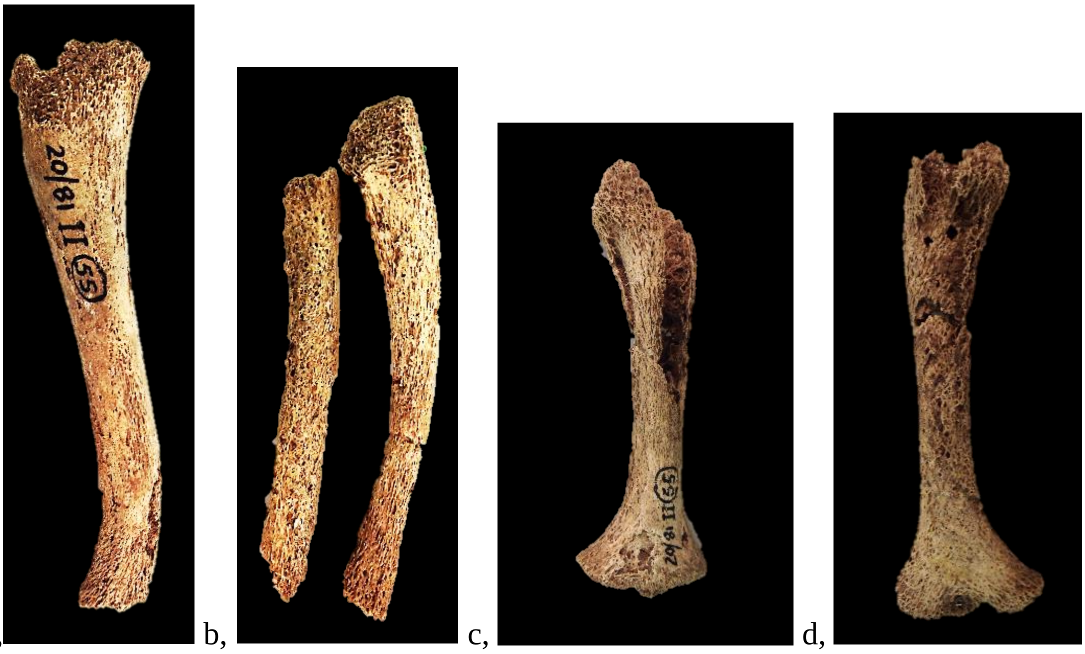
a,  *b,* 

Figure 5.36. Possible thalassaemia at Butt Road III. Close up radiographs of localised masses on ribs superior (left) and inferior (right). Radio-opaque appearance of the localised masses on top of the original cortex. From Butt Road, Colchester, skeleton 145. (with permission from Colchester and Ipswich Museums)

Figure 5.37. Possible thalassaemia at Butt Road IV. Superior view of ribs with localised masses of lamellar bone. From Butt Road, Colchester, skeleton 145. (with permission from Colchester and Ipswich Museums)

5.3.4.6.2. Skeleton 55, 35 Kingsholm Road, Gloucester

Skeleton 55 is only represented by one skull fragment, and long bones of the upper and lower limbs, and appears to be an infant. It is likely that this infant was affected by both vitamin C and D deficiencies (Roberts 1989). A differential diagnosis of thalassemia may potentially also apply, however a definite diagnosis for thalassaemia cannot be made as the ribs are missing, as rib-within-a-rib is pathognomonic of the disorder. The epiphyses of the long bones are splayed and enlarged, with severe bowing observed in the right ulna and left tibia which are diagnostic of rickets (Fig. 5.38). Long bones appear swollen yet wasting, as the individual bone elements themselves are enlarged but the cortical bone is thinned, pitted and porous. The trabecular structure is reduced with enlarged and reinforced cancellous bone indicative of osteopenia (Figs. 5.39 and 5.40). There is extensive disorganised new bone formation on top of the original cortex of the humerus and femora (Figs. 5.38 and 5.39). There are no cranial elements present for observing porotic hyperostosis or cribra orbitalia. Although the skull and ribs are missing for providing more conclusive evidence for thalassaemia, the changes observed in the long bones are suggestive of a chronic condition additional to the rachitic/scorbutic lesions. As this individual died in infancy, it may be likely that the skeletal lesions are a product of thalassaemia major and severe nutritional deficiency.



a, b, c, d,

Figure 5.38. Possible thalassaemia as a differential diagnosis I. a: left tibia anteriorly with lateral bowing of the distal half of the shaft; b: right radius and ulna anteriorly with medial bowing of the ulnar shaft, c and d: anterior and posterior view of the left humerus with slight bowing of the shaft, enlarged distal epiphysis and extensive woven bone deposits on the supero-distal margins, enlarged trabecular structure. All four elements display porosity and thinning of the cortex. From 35 Kingsholm Close, Gloucester, skeleton 55. (with permission from BARC)

a, b, c,

Figure 5.39. Possible thalassaemia as a differential diagnosis II. Right and left femora anterior (a), medial (b), posterior (c). Enlarged trabecular structure at proximal and distal epiphyses, cortical thinning and pitting of cortex throughout. Left femur antero-distal aspect and right femur medio-proximal aspect with complete destruction of the cortical bone and expansion of the underlying trabeculae. From 35 Kingsholm Road, Gloucester, skeleton 55. (with permission from BARC)

Figure 5.40. Possible thalassaemia as a differential diagnosis III. Radiograph of all long bones, clavicular and cranial fragments of skeleton 55, 35 Kingsholm Road. Note the thinning cortex in the long bones and enlarged trabecular structure. (with permission from BARC)

5.3.4.6.3. Skeleton 73, 35 Kingsholm Road, Gloucester

Individual 73 was aged to within the first few months of life, possibly 4-8 weeks based on skeletal maturation. The skeleton is eroded and lacks hands/feet, the spine and ribs, and most of the cranium. The individual shows evidence for vitamin C/D deficiencies. Cranial fragments show increased porosity on the ectocranial aspects with widespread marrow expansion. The body of the right mandible is pitted and porous throughout. The left frontal bone shows marked pitting and porosity of the ectocranial cortex around the orbit (Fig. 5.41). All cranial elements appear slightly thickened. The long bone fragments display pitting and cortical thinning throughout (Figs. 5.42 and 5.43). The cranial lesions in isolation may be attributed to vitamin C/D deficiency, and the absence of the ribs prevents a diagnosis for thalassaemia with certainty. However, the trabecular thickening of the frontal bone around the orbits, generalised marrow expansion and thinning of the cortex of the long bones may suggest a potential differential diagnosis for thalassaemia intermedia.

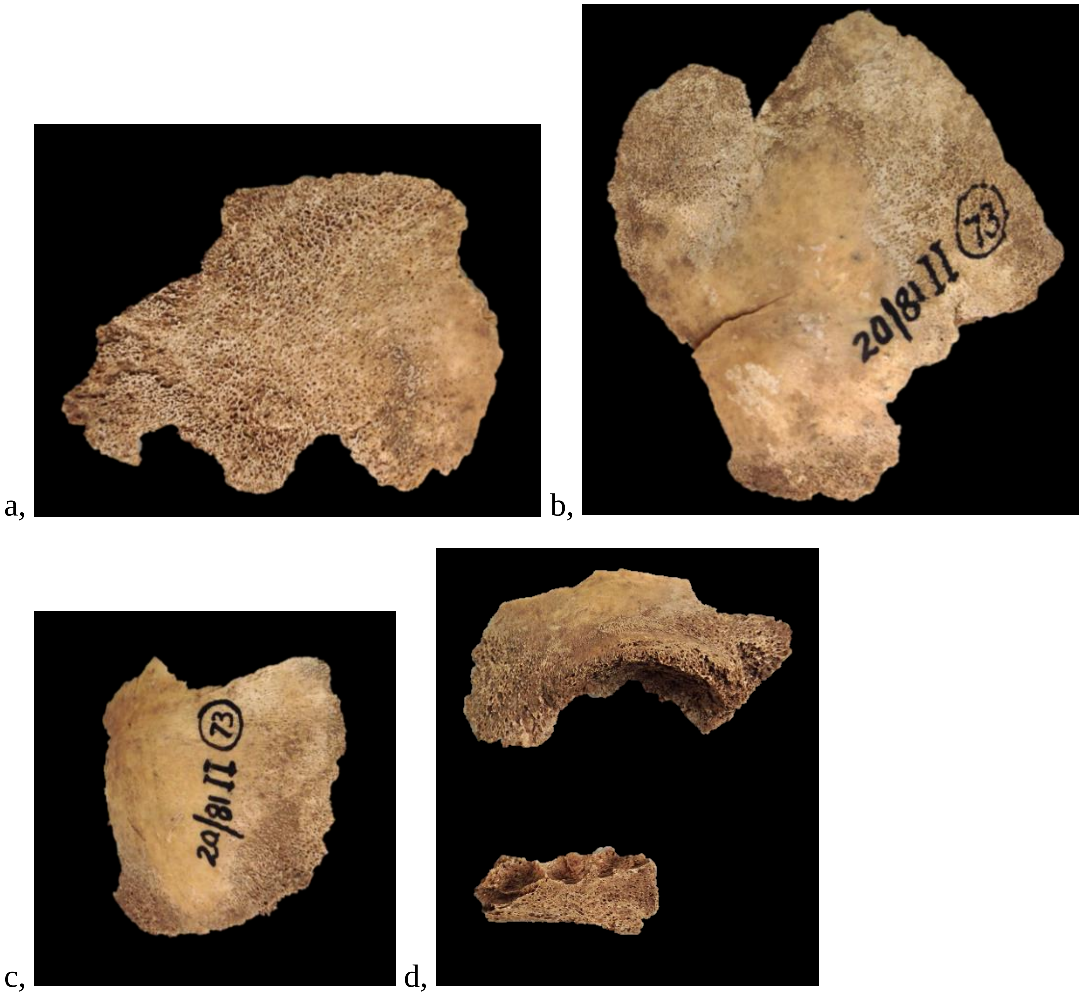


Figure 5.41. Possible thalassaemia as a differential diagnosis IV. Skull fragments ectocranial, with marrow expansion (a, b, c). d, thickened right orbit with increased porosity and left mandibular body with pitting and porosity of the cortical bone. From 35 Kingsholm Road, Gloucester, skeleton 73. (with permission from BARC)

Figure 5.42. Possible thalassaemia as a differential diagnosis V. Long bones with pitting and cortical thinning. From 35 Kingsholm Road, Gloucester, skeleton 73. (with permission from BARC)

Figure 5.43. Possible thalassaemia as a differential diagnosis VI. Radiograph of the long bones of skeleton 73, 35 Kingsholm Road, displaying cortical thinning and enlarged trabeculae. (with permission from BARC)

5.3.4.7. Specific infectious diseases

Two individuals from major urban contexts have been reported that display lesions indicative of a specific infection: leprosy and brucellosis. The lepromatous non-adult from Roman Gloucester has been reported previously in the literature by Lewis (2002a), whereas possible brucellosis in skeleton 709 from Cirencester marks a new differential diagnosis for the vertebral lesions observed. Both are presented as case studies below.

The unprovenanced individual from the Gambier-Parry Lodge site at Roman Gloucester displayed cranio-facial lesions indicative of infection with *Mycobacterium leprae*. The non-adult is represented by the skull only, with a mean dental age of 8.5 years. The facial lesions are representative of rhino-maxillary syndrome (Lewis 2002a, 166) (Fig. 5.44). The individual displays erosion of the nasal spine, with widening of the nasal aperture. The margins of the piriform aperture are increasingly rounded. The medial aspects of the frontal process of the maxillae show disorganised widespread resorption of the cortical bone bilaterally. The mandible does not display any bony changes which is characteristic of lepromatous infections (Aufderheide and Rodriguez-Martin 1998, 151; Ortner 2003, 266).

Figure 5.44. Unprovenanced non-adult from Gambier-Parry Lodge with rhino-maxillary syndrome. (with permission from BARC)

Destructive lesions on vertebral bodies possibly indicative of brucellosis have been found in one individual from the major urban cemetery at Bath Gate, Cirencester (Figs 5.45 to 5.48). Skeleton 709 was aged between 10.6-14.5 years based on long bone length and skeletal maturation. Only elements of the spine, ribs and long bones are present. Vertebral bodies of the thoracic spine displayed multifocal lytic lesions with sclerotic margins on the anterior and lateral aspects. One vertebral body of the upper thoracic spine is compressed in height on the left lateral portion. There is complete destruction of the superior left lateral margin and end plate of the vertebral body with remodelling of the collapsed bone surface (Fig. 5.48). A tentative suggestion behind this lesion may be that it is the result of a compression fracture secondary to lytic destruction as seen in the other vertebral bodies. Tuberculous kyphosis may apply to the vertebral pathologies observed, however this condition normally involves one to four vertebrae and no other lesions suggestive of tuberculosis have been found in the ribs or appendicular skeleton. Brucellosis is difficult to diagnose (Ortner 2003, 217), and an additional caveat is the absence of overhanging osteophytes and any additional lesions suggestive of brucellosis such as lytic foci in the pelvis in this individual (Mays 2007). However, the sclerotic margins of the multifocal lytic lesions seen in six adjacent thoracic vertebral bodies suggest a widespread condition rather than localised trauma, and seem unusual for tuberculosis. As a provisional diagnosis brucellosis may be considered.

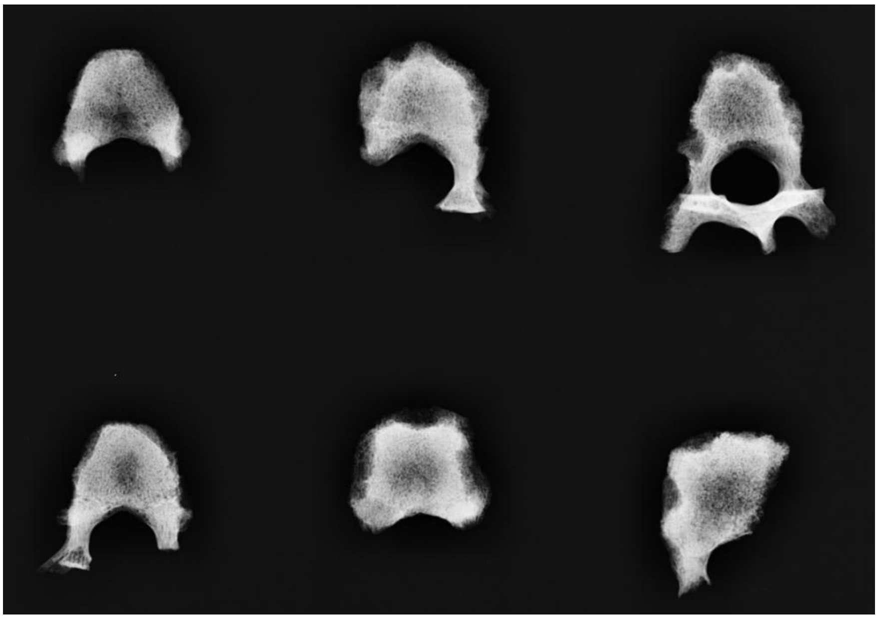


Figure 5.45. Possible brucellosis I. Radiograph of thoracic vertebrae, inferior aspect; displaying resorptive foci on anterior and lateral vertebral margins. From Bath Gate, Cirencester, skeleton 709. (with permission from Corinium Museum)

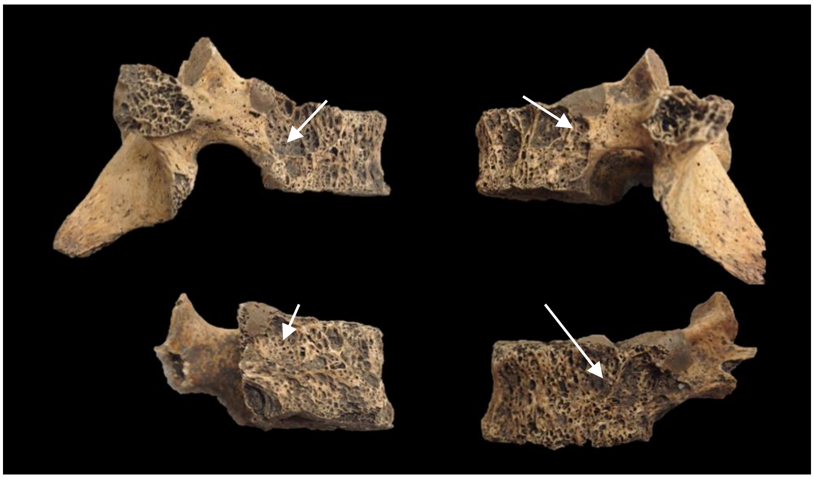


Figure 5.46. Possible brucellosis II. Lateral aspects of vertebral bodies with circular resorptive foci displaying rounded sclerotic margins. From Bath Gate, Cirencester, skeleton 709. (with permission from Corinium Museum)

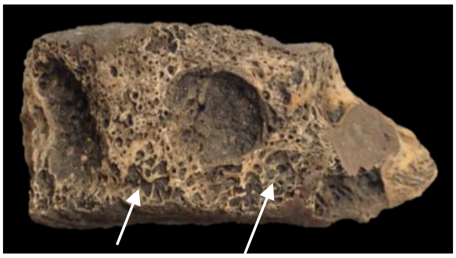


Figure 5.47. Possible brucellosis III. Left lateral aspect of vertebral body with circular lytic focus with sclerotic margins; post-mortem damage with arrows for comparison. From Bath Gate, Cirencester, skeleton 709. (with permission from Corinium Museum)

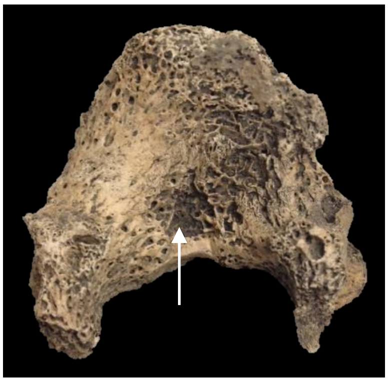
a,  b, 

Figure 5.48. Possible brucellosis IV. a, superior view of vertebral body with collapse of the left portion of the end plate and body with loss of the superior joint surface apart from the anterior and right lateral margin (arrow marks post-mortem damage); b, left antero-lateral view of compression in height of vertebral body with new cortical bone on the superior and lateral margins. From Bath Gate, Cirencester, skeleton 709. (with permission from Corinium Museum)

5.3.4.8. Tuberculosis

New cases of probable and possible childhood tuberculosis in Roman Britain have been identified in this study which have not been discussed before in the literature. In the primary study sample, a total of six individuals exhibited skeletal lesions indicative of tuberculosis, three (CPR 2.5%) in major urban, two (CPR 1.3%) in minor urban and one (CPR 3.6%) in rural non-adults. Some of these diagnoses are very tentative and mark possible as opposed to probable cases of tuberculosis, with all cases presented below with a differential diagnosis. The distribution is not statistically significant (X^2=1.38) (Table 5.12, Fig. 5.15). The rural case is from Cannington in Somerset, which is likely to be a respiratory infection. The two minor urban cases include one individual from Ashton, Northamptonshire, with a mean age of six years (skeleton 126), and one individual from Ancaster, Lincolnshire with a mean age of seven years (skeleton 55). There are four individuals from major urban sites with possible tuberculosis. One individual is a 10-year old from Trentholme Drive, York, Yorkshire (skeleton 31). Two individuals are from the main cemetery at Butt Road, Colchester in Essex, aged 5.5 (skeleton 672) and 11.5 years old (skeleton 376). One individual aged 14 years old from the main cemetery at Bath Gate, Cirencester in Gloucestershire, was buried prone (skeleton 299). The possible and probable cases are listed as case studies below.

5.3.4.8.1. Skeleton 31, Trentholme Drive, York

Skeleton 31 has been aged between 7.5 and 12.5 years, with a mean age of 10 years based on the resorption of the roots of the first deciduous molar. Although teeth were present, the individual was otherwise represented by postcrania only. The left ribs are marked with severe periosteal new bone formation on the pleural aspect, with isolated lytic foci (Fig. 5.49). No right ribs were present to check for bilateral lesions. There was widespread sub-periosteal new bone formation on the left tibial shaft, and on both left and right calcaneii. The right fibula appears swollen mid-shaft, with widespread periosteal new bone and cortical thickening indicative of osteitis. Periosteal new bone on the ribs and long bones may imply a respiratory infection alone, however tuberculosis may also be suggested as a likely cause behind these lesions taking into account the infection of the fibular cortex.

Figure 5.49. New bone formation on ribs I. Left ribs (superior) with new bone formation on pleural aspect of heads and shaft. From Trentholme Drive, York, skeleton 31. (with permission from NHM London)

5.3.4.8.2. Skeleton 376, Butt Road, Colchester

Butt Road 376 has a mean dental age of 11.5 years and is a relatively complete skeleton. This individual had enamel hypoplasia, dental disease, osteochondritis dissecans and displayed lesions suggestive of tuberculosis (Fig. 5.50). Minimal periosteal new bone formation is evident on the ribs bilaterally. Lytic foci with destruction of the cortical and underlying trabecular bone are found on rib shafts bilaterally and towards the sternal ends especially. The lumbar and sacral spine is marked by lytic foci of bone resorption. Lumbar vertebrae 1 through to 5 are affected on the anterior aspects of the vertebral bodies. Sacral vertebra 1 also displays a lytic lesion on the anterior aspect of the body. One first metacarpal appears swollen with a ballooned cortex and periosteal new bone formation indicative of dactylitis. Bilaterally the iliac blades display resorptive foci on the cortex both medio-anteriorly and adjacent to the auricular surfaces, with localised areas of periosteal new bone. The widespread skeletal changes seen in skeleton 376 are indicative of tuberculosis, possibly gastro-intestinal in origin given the lesions in the lower spine and pelvis.

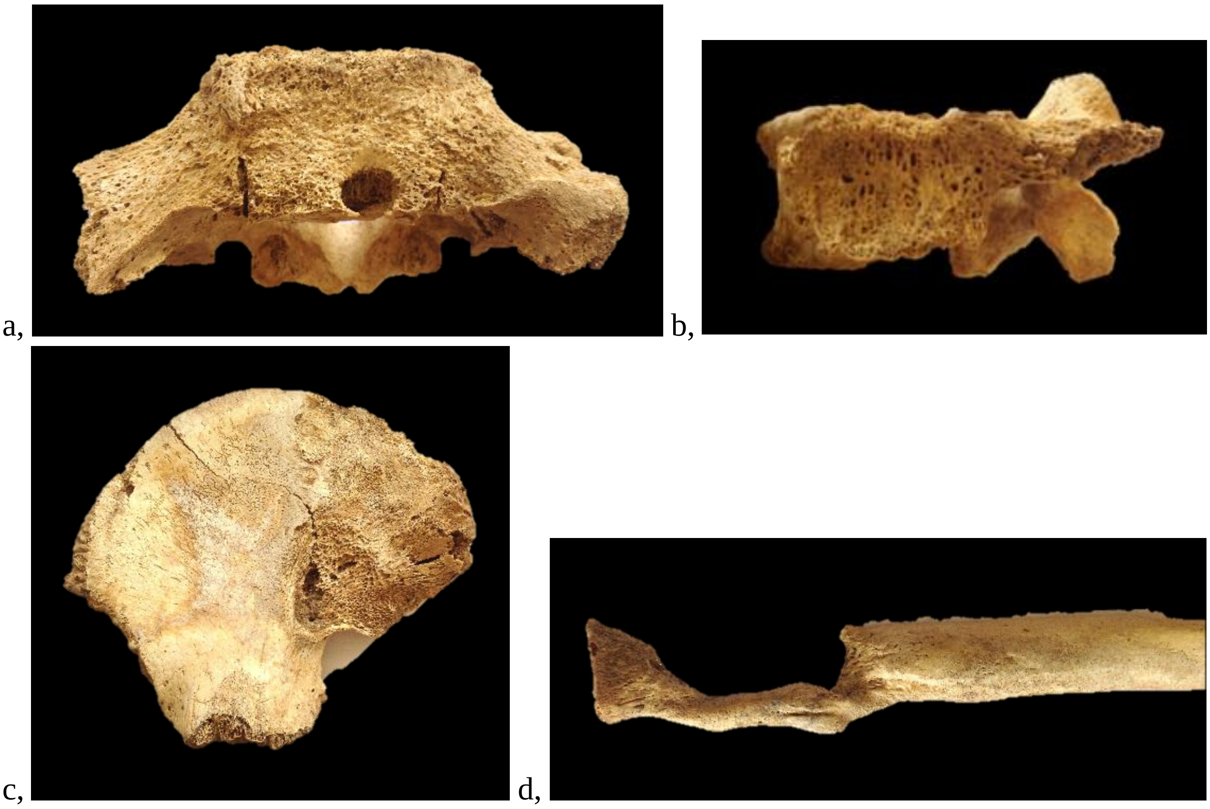


Figure 5.50. Probable tuberculosis I. a, lytic focus on the inferior vertebral body of S1; b, resorptive focus on anterior vertebral body of T5; c, new bone formation on the medial aspect of the right ilium; d, left rib inferio-medial with resorption and lytic lesion, also new bone formation on visceral aspect. From Butt Road, Colchester, skeleton 376. (with permission from Colchester and Ipswich Museums)

5.3.4.8.3. Skeleton 672, Butt Road, Colchester

Skeleton 672 has a mean dental age of 5.5 years. The individual is relatively well preserved and represented, with only the hands and feet missing. Healing cribra orbitalia Stage 3 was observed bilaterally. There is periosteal new bone formation on the visceral aspect of rib heads bilaterally. Some of these lesions are healing and the woven bone is smoothing over into cortical bone whilst displaying initial lytic foci. There is one right rib head with a large resorptive lesion on the vertebral aspect with sclerotic margins and without new bone formation, possibly as a result of a psoas abscess. Lesions indicative of Pott’s disease were found in the upper thoracic spine, affecting T1 to T3. T1 and T2 are fusing at the left articular facets, T2 and T3 are fusing at the left pedicle and lamina, with destruction of the vertebral body of T2 (Fig. 5.51). Although fusion of vertebral elements after spinal collapse in tuberculosis cases is not common, it may still occur as the periosteum reacts to the destruction of the vertebral body (Aufderheide and Rodriguez-Martin 1998, 137). Based on the destructive lesions in the spine, lytic lesions and new bone formation observed in the ribs, and rib lesion possibly associated with a psoas abscess, a diagnosis of tuberculosis is plausible for this individual.

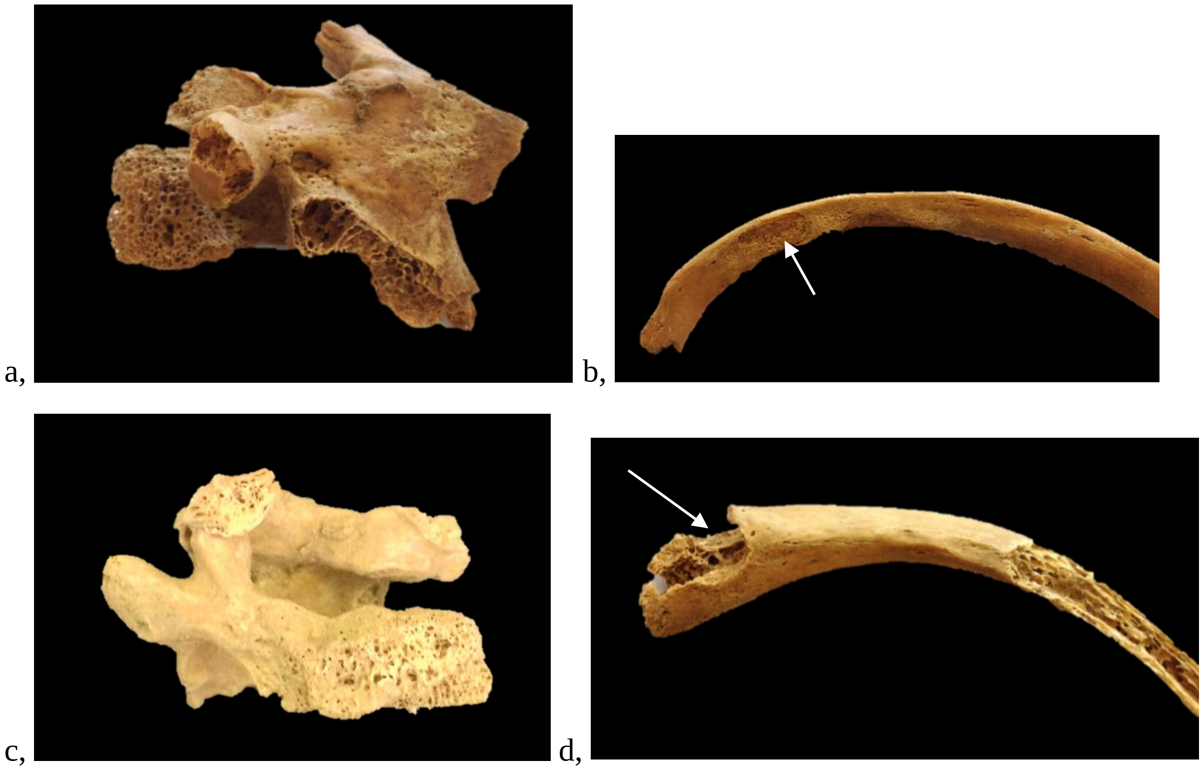


Figure 5.51. Probable tuberculosis II. Left lateral (a) and right lateral (c): destruction of the vertebral body of T2, and fusion of T2 and T3 at the left pedicle and lamina indicative of Pott's Disease; b, right rib inferiorly with new bone formation and lytic foci in sub-periosteal new bone; d, right rib inferiorly with large circular lytic lesion on the vertebral aspect of head. From Butt Road, Colchester, skeleton 672. (with permission from Colchester and Ipswich Museums)

5.3.4.8.4. Skeleton 55, Ancaster

Individual 55 has a mean dental age of 6.5 years, with good preservation and representation. Active Type 4 endocranial lesions with hair-on-end were located on the occipital sulcus and cruciate eminence. Ribs were affected by periosteal new bone formation along the pleural aspect of the sternal ends and on the mid-shaft. A lytic focus in the periosteal new bone was identified in one unsided rib fragment. Both left and right ulnae show extensive periosteal new bone formation on the lateral portion of the head. Widespread active periostitis was also found on the anterior portion of the distal femora, distal shaft of the tibiae and fibulae. No lesions were noted in the spine, and given the skeletal changes indicative of a respiratory infection, tuberculosis is only a speculative cause behind the skeletal lesions observed in skeleton 55.

5.3.4.8.5. Skeleton 126, Ashton

Skeleton 126 has a mean age of six years, with a well preserved and represented skeleton. Active endocranial lesions Types 2, 3 and 4 have been recorded on parietal fragments, the latter with hair-on-end. Healing type 3 and 4 lesions were spread over the cerebral and cerebellar fossae of the occipital. The cortical bone of the postcrania appears thinned. Localised healing periosteal bone growth was found on the medial aspect of the tibial mid-shafts bilaterally. Both ilia show widespread active periostitis on the medial aspect of the blades, particularly around the auricular surface.

Vertebral bodies of the sacrum and L5 are eroded but still display evidence for destructive resorption. S1 appears with a large lytic lesion towards the left lateral portion of the vertebral body, and there is a lytic lesion on the superior aspect of the vertebral body of L5 (Fig. 5.52). Although the spinal lesions are not reflecting Pott’s disease, the destruction of vertebral bodies and lesions in the ilia suggest potential tuberculosis which may have been gastro-intestinal in origin.

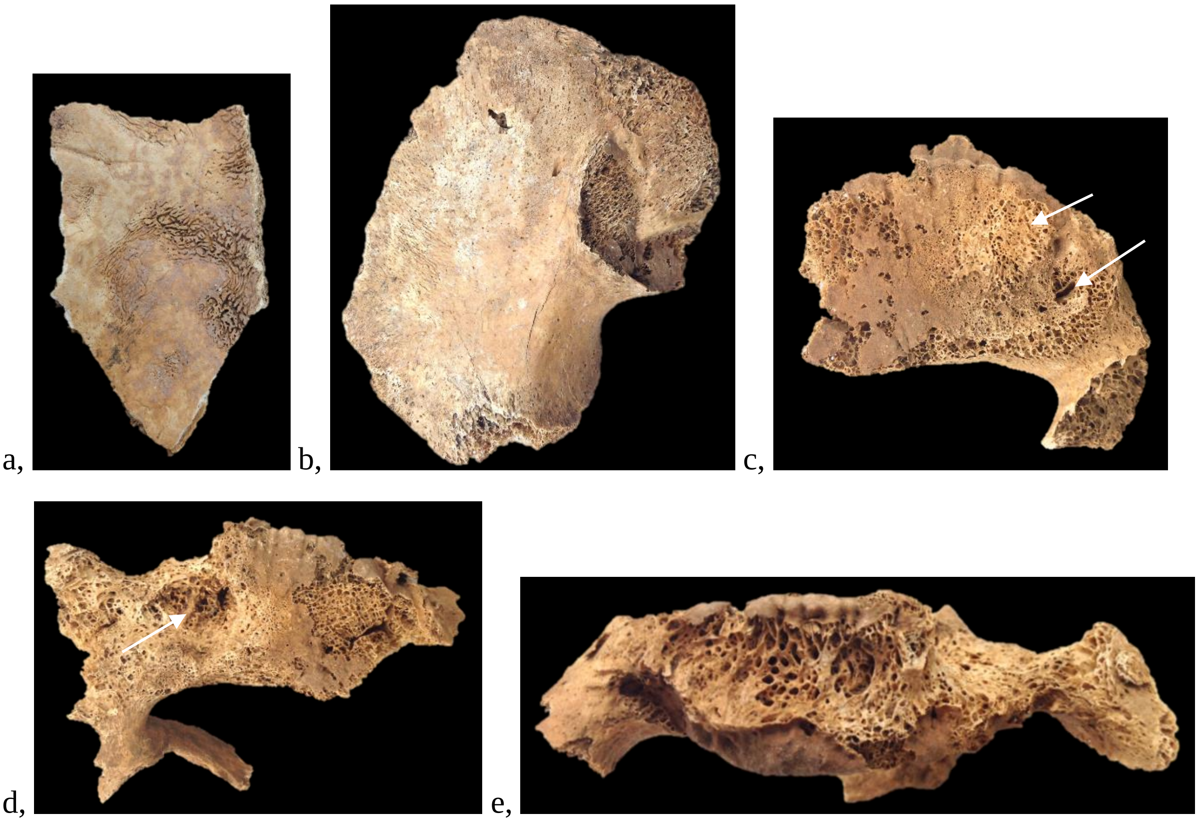


Figure 5.52. Probable tuberculosis III. a, Type 4 endocranial lesion on parietal fragment; b, widespread periosteal new bone formation on medial aspect of right ilium; c, L5 superiorly with eroded and resorptive destruction of vertebral body; d, S1 superiorly with circular lytic lesion;e, S1 anteriorly with destruction of the anterior margins of sacral body. From Ashton, skeleton 126. (with permission from Peterborough Museum)

5.3.4.8.6. Skeleton 51b, Cannington

Burial 51b from Cannington in Somerset has a mean skeletal and dental age of 15 years and is likely to be male. Active Type 3 endocranial lesions were recorded on the parietals bilaterally, and the occipital bone around the cruciate eminence and the superior aspects of the cerebral fossae, as well as unidentified skull fragments. Rib fragments showed periosteal new bone formation on the pleural aspect, with small lytic foci within the new bone deposits (Fig. 5.53). Widespread active periosteal new bone formation was recorded on the femoral and tibial shafts bilaterally. The spine is only represented by three thoracic and three lumbar fragments, and it was therefore not possible to assess for Pott’s disease or other spinal lytic lesions which poses a caveat for a potential diagnosis of tuberculosis. It is likely that this individual suffered from a respiratory infection.

Figure 5.53. New bone formation on rib II. Right rib medially with periosteal new bone on visceral aspect, and lytic foci. From Cannington, skeleton 51b. (with permission from NHM London)

5.3.4.9. Non-specific respiratory disease

An addition to the three above cases considered for tuberculosis and with respiratory infection as a differential diagnosis, 10 cases have been identified with skeletal lesions indicative of respiratory disease: two non-adults from minor urban sites and eight non-adults from major urban contexts. This raises the total to 13 cases of respiratory disease. The true prevalence rates for individuals with new bone formation on the visceral aspect of the ribs are displayed in Table 5.32. The distribution is not statistically significant (X^2=5.75).

Table 5.32. Distribution of periosteal new bone formation on visceral aspect of ribs

	Major urban	**Minor urban**	**Rural**	**Total**
n with rib lesions	9	3	1	**13**
N with ribs	207	210	116	**533**
TPR (%)	**4.3**	**1.4**	**0.9**	**2.4**

These individuals displayed sub-periosteal new bone formation on the visceral aspect of the ribs, which are indicative of a pulmonary infection such as pneumonia or bronchitis (Roberts et al. 1994; Santos and Roberts 2001; Matos and Santos 2006). According to Pfeiffer (1991), rib lesions observed as plaque or puffy cortical expansion are likely to be a result of non-specific inflammatory periostitis on the ribs. Dense layers of periosteal new bone mark the response to an initial acute infection, which were recorded in seven individuals. Whereas a puffy and porous expansion of the cortical bone is a result of a more chronic response to a respiratory ailment and was only found in one individual from Trentholme Drive, York (skeleton 318). The two minor urban cases comprise of a 4-year old from Ashton (skeleton 129) and a 14-year old from Baldock (skeleton Bal15’94 2025). Skeleton 129 also exhibited enamel hypoplasia on the deciduous canines. Both active and healing sub-periosteal new bone growth on the visceral aspect of right rib heads and shafts, as well as the inferior margins of the shafts were observed. The periostitis is exclusively unilateral with no lesions on the left ribs. Bal15’94 2025 was recorded with Grade 3 active cribra orbitalia, enamel hypoplasia, osteochondritis dissecans in the spine and dental disease. Healing periosteal new bone deposits on the left ribs were observed, with right ribs 2 and 3 congenitally fused. Respiratory disease in major urban contexts is suspected in four individuals from Bath Gate, Cirencester (skeletons 47, 181, 259 and 299), two individuals from Trentholme Drive, York (skeletons 318 and 465), and one individual from Butt Road, Colchester (skeleton 545). Skeleton 47 at Bath Gate with a mean age of 15 years displayed localised active woven bone deposits on an unsided rib fragment. Skeleton 181 with a mean age of 7.5 years had active Type 3 endocranial lesions on the occipital transverse sulci, enamel hypoplasia, and showed healing and active localised periosteal new bone deposits on the visceral aspect of rib heads and shafts on the right side only. No new bone formation was recorded on the left ribs. Skeleton 259 was aged to around 2.5 years old, with enamel hypoplasia in the permanent molars and active Grade 4 cribra orbitalia. Active periosteal new bone deposits were found on ribs bilaterally, on the visceral aspect of rib heads, and visceral and lateral aspects of rib shafts. New woven bone deposits were also recorded on the inferior aspect of the right clavicle at the mid-shaft. Individual 299 from Bath Gate has a mean dental age of 14 years with enamel hypoplasia on the canines. Active Type 4 endocranial lesions were found as localised patches on the frontal bone. The cranial bones are thickened throughout. Rib ends and shafts were coated with a fine layer of periosteal new bone on the visceral aspect, and long bones of the upper and lower limbs also display localised active periostitis, which are indicative of a respiratory infection At Trentholme Drive in York, skeleton 318 with a mean age of 16 years displayed cortical thickening of the right rib shafts resulting in a ballooned appearance. The expanded cortical bone is likely to be due to a chronic response to inflammatory periostitis secondary to pulmonary infection. This individual also displayed spondylolysis in T5 and osteochondritis dissecans in the superior articular facets of T1 through to T4. Skeleton 465 with a mean age of 11 years presented with recurrent bouts of pulmonary infection and enamel hypoplasia. The right ribs show layers of healed periosteal new bone at the visceral aspect of the heads and shafts. There are also isolated foci of pitted and vascular active new bone deposits on the visceral aspect and inferior margins of shafts. The lesions are unilateral. Lastly skeleton 545 at Butt Road, aged around seven years old, exhibited a fine layer of healing periosteal new bone deposits on two right rib heads at the visceral aspect. The lesions are unilateral with no new bone formation found on the left side.

5.3.4.10. Trauma

Healing or healed fractures have been recorded in a total of 16 individuals (CPR 1.7%) from all three site types using the guidelines set out in Ortner (2003, 120-128). Previously reported trauma in the primary study sample included only two cases, a probable Monteggia fracture at Cannington, and a clavicular fracture at Queenford Farm/Mill. Trauma was found in 1.8% (n=7) of non-adults from major urban sites, which marks the lowest crude prevalence rate for trauma in the sample. In rural contexts, 1.9% (n=4) of individuals were affected, which marks the highest crude prevalence rate. Three of the four cases were recorded in the Cannington assemblage. Three of the four fracture cases from rural cemeteries involve the clavicle, with a predilection for the left side. Trauma was recorded in minor urban individuals at CPR 1.5% (n=5). All of the fractures either displayed evidence of healing or were healed with smoothing of the fracture callus and remodelling into trabecular bone. Where the element affected could be sided, apart from phalangeal and vertebral fractures, the left side (n=8) was more often affected than the right (n=5). Overall, long bones exhibited trauma most frequently (43.8%, n=7), and the majority of fractures were confined to elements of the upper limb (Table 5.33).

Table 5.33. Fracture distribution by location

	Major urban		**Minor urban**		**Rural**		**Total**	
	n	*%*	*n*	*%*	*n*	*%*	***n***	***%***
Upper limbs	4	57.1	2	40.0	4	100	**10**	**62.5**
Lower limbs	1	14.3	3	60.0	0	0	**4**	**25.0**
Axial	2	28.6	0	0	0	0	**2**	**12.5**
Total N	7		5		4		**16**	

All of the clavicular fractures occurred at the mid-shaft indicating a fall onto the shoulder or the outstretched arm, where the force of the momentum of the fall is directed into the clavicle (Ogden 2000, 431). Three of the five cases of clavicular fractures occurred in older children above the age of 12 years old, a 5-year old from Cannington was also affected. The youngest individual with a fractured clavicle is an infant of around three months at Bradley Hill in Somerset (skeleton 93/182 F123). The fracture is well healed and remodelled. Considering the rapid fracture healing and bone remodelling in infancy, this fracture may have arisen as early as at birth. Clavicular fractures can occur in perinates with increased birthweight or during difficult deliveries such as shoulder dystocia (Gherman et al. 1998; Ogden 2000, 431).

Skeleton 170, aged 10.6-14.5 years, from Cannington displays evidence for the Monteggia injury with posterior bowing of the proximal third of the left ulnar shaft and head, with a poorly developed radial head indicative of dislocation or subluxation (Ogden 2000, 594). The radiograph shows thickening of the cortical bone at the proximal shaft, although the fracture line has healed completely. This healed fracture (potentially greenstick) has led to a posterior tilt in the ulnar head which also resulted in thinning of the left radius and reduced size of its head, indicative of dislocation (Fig. 5.54). Monteggia lesions arise from falls onto an outstretched hand, where the weight of the body is transmitted along the upper limb with the radio-ulnar joint in full pronation (Ogden 2000, 596). One of the complications associated with Monteggia lesions is chronic dislocation and malposition (Ogden 2000, 602), which would have affected the left arm of this individual. This fracture case has been reported previously in Brothwell et al. (2000, 207-211) and interpreted as an old greenstick fracture.

Figure 5.54. Probable Monteggia injury. Radiograph of ulnae (medial) and radii (posterior). Left ulna (left) with posterior angulation of proximal shaft and head, cortical thickening. Left radius (left) with cortical thinning and weakened trabecular structure of the head, altered head, neck and radial tuberosity. From Cannington, skeleton 170. (with permission from NHM London)

Minor urban sites have yielded one clavicular fracture, and two individuals with healed fractures in the long bones. The right mid-shaft clavicular fracture in a 12-year old from Queensford Farm/Mill (skeleton 51/232) (Fig. 5.55) has been previously reported by Chambers (1987). Additional trauma cases from minor urban sites include one left tibial fracture in an 11.5-year old from Dunstable (skeleton AI), and a right femoral fracture in a 2-year old from Queensford Farm/Mill (skeleton 20/204), which had not been reported previously. The latter would have resulted from a violent injury involving considerable blood loss and shock (Ogden 2000, 880). The left tibial fracture at the mid-shaft in skeleton AI from Dunstable resulted in slight angulation and increased length of the bone. This type of diaphyseal fracture results from a direct blow to the element or a twisting force to the foot that is conveyed along the tibial shaft, and in either case requires a considerable amount of force (Ogden 2000, 1035). The response caused by the inflammation at the fracture site may stimulate rather than inhibit bone growth and result in increased growth of the affected long bone (Ortner 2003, 130). It is likely that this individual would have walked with a limp to compensate for the differences in length in the left and right lower limbs (Figs. 5.56 and 5.57). A 14.5-year old male from Baldock (skeleton 1496) showed evidence for a phalangeal fracture in the hand. Ankylosis likely to be secondary to a fracture of the second and third foot phalanges was found in a 15.5-year old female from Dunstable (skeleton CK/T1343). These fractures are relatively common and may arise from a variety of mechanisms, such as falls and crushing (Ogden 2000, 678, 1138).

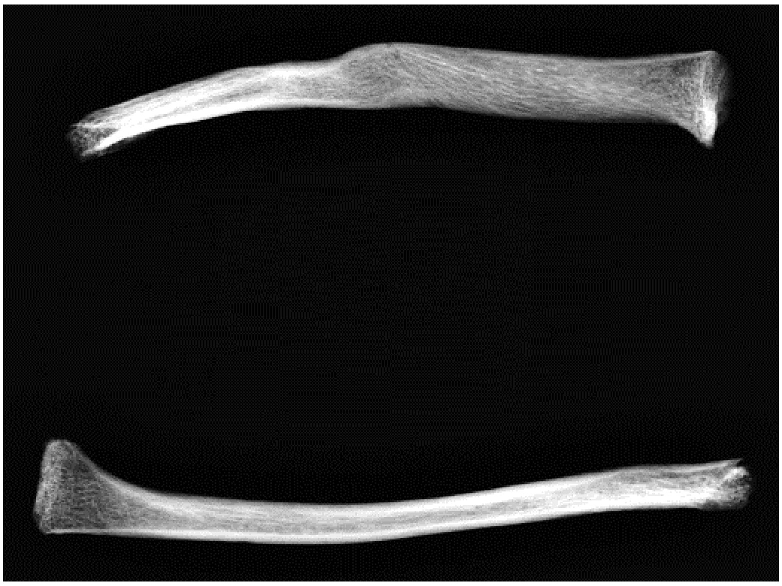


Figure 5.55. Healed clavicular fracture. Anterior-posterior view of right (top) and left (bottom) clavicle. Right clavicle with healed mid-shaft fracture. From Queensford Farm/Mill, skeleton 51/232. (with permission from Oxfordshire Museums Service)

Figure 5.56. Tibial fracture. Anterior view of left (top) and right (bottom) tibia. Healed fracture at the mid-shaft in the left tibia resulted in elevated growth. From Dunstable, skeleton AI. (with permission from Luton Culture)

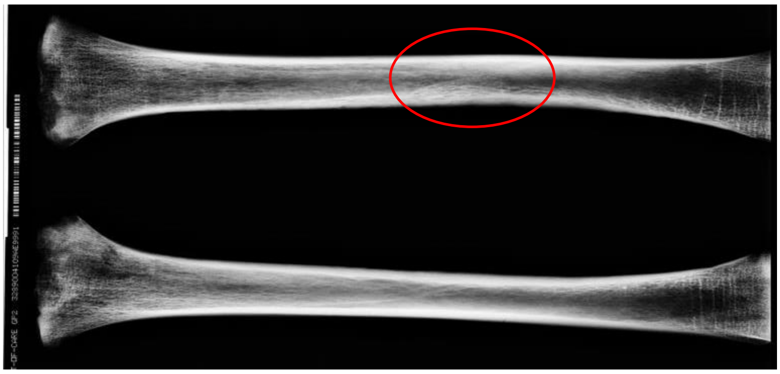


Figure 5.57. Radiograph of tibial fracture. Posterior view of left (top) and right (bottom) tibia. Healed fracture at the mid-shaft in the left tibia with increased cortical thickness. Note a general decrease in cortical thickness in the left tibia compared to the right. From Dunstable, skeleton AI. (with permission from Luton Culture)

In major urban sites, one rib, one clavicular, one vertebral (sacral) and three long bone fractures have been recorded. The healed left clavicular fracture in a 16.5-year old from the cemetery at Trentholme Drive, York (skeleton 731) possibly resulted in a prolonged period of inactivity of the left upper limb, with shortening and decreased robusticity of the left humerus, radius and ulna compared to the right. The complete fracture in a rib of an infant of around three months from Winchester (skeleton VRE444 from Victoria Road East) is indicative of either blunt chest trauma or a difficult delivery (Barry and Hocking 1993) (Fig. 5.58). The rib fracture in this case displays a fracture callus, and therefore would not have interfered with lung function or stability of the chest wall due to a free-floating rib fragment. The thorax is very resilient to fractures due to its elastic properties that allow it to deform and ultimately lower the risk for skeletal trauma. In modern clinical cases, rib fractures are associated with vehicle accidents or child abuse (Ogden 2000, 422-424). Rib fractures in infants are infrequent, and when encountered are often associated with deliberate injury. Kleinman et al. (1996) observed 165 fractures in abused infants, 51% of which involved the ribs. Rib fractures result from anterior-posterior compression mainly induced by shaking, or the infliction of direct force onto the thorax (Kleinman et al. 1996; Bulloch et al. 2000). Bulloch et al.'s (2000) study on 39 infants with one or more rib fractures identified 82% of their patients to have been the victim of abuse. However anteriorly located bone lacerations, as the one observed at Winchester only made up 6% of the total fractures in their sample. Barsness et al. (2003) reported a higher rate for anterior fractures at 22%. The infant VRE444 did not display any additional traumatic and pathological lesions that may indicate abuse, but in Barsness et al. (2003) one or more rib fractures were the sole skeletal indicator of abuse in 82.3% of 62 children with broken ribs under the age of three years. An additional non-traumatic cause for a rib fracture in an infant may be the possibility of pressure being exerted on the ribs during swaddling and when the infant was picked up, especially when bone is weakened due to vitamin D deficiency (Lewis 2010). Lovell (1997) also noted the possibility of stress fractures as a result of continuous coughing or vomiting, although these are less common than breaks due to direct trauma. The absence of any other skeletal markers of nutritional stress, metabolic disease or infection, as well as any new bone formation on the pleural aspect of the ribs as a result of pulmonary infection may however make persistent coughing or vomiting an unlikely cause. Lastly, the fracture may have been sustained during complications in labour, such as shoulder dystocia, which normally results in a clavicular fracture, but should also be considered for a differential diagnosis of rib fractures (Bulloch et al. 2000; van Rijn et al. 2009). It is impossible to identify whether the infant at Victoria Road East sustained a rib fracture due to swaddling, was abused by its care-givers, or was the victim of an accident, as all three are equally likely.

Figure 5.58. Rib fracture. Inferior view of left rib with fracture callus. From Victoria Road East, Winchester, skeleton 444. (with permission from Winchester Museum Service)

A 15.5-year old from Bath Gate, Cirencester (skeleton 63) had a healed mid-shaft fracture in the right tibia, following a similar fracture mechanism as the trauma to the tibia in skeleton AI from Dunstable (Fig. 5.59). The radiographs show thickening of the cortical bone around the fracture site and woven bone formation around the medullary cavity at the fracture site. A possible compression fracture of the third sacral vertebra of an 11-year old (skeleton 231) was also recorded at Cirencester. The third sacral vertebra of skeleton 231 exhibits wedging of the left half of the vertebral body with compression of the body in height and width.

a, b, c,

Figure 5.59. Right tibia with healed mid-shaft fracture. a, photograph medial; b, radiograph anterior; c, radiograph lateral. From Bath Gate, Cirencester, skeleton 63. (with permission from Corinium Museum)

Fractures in the upper limb affected one left humerus at the mid-shaft, and a right radius at the distal diaphysis in two individuals from the cemetery at Butt Road, Colchester. An 11-year old (skeleton 595) was found with a healed proximal physeal fracture on the left humerus. The fracture lead to severe shortening and angulation of the humeral diaphysis, and changes in the proximal and distal epiphyses, which would have affected overall mobility of the left upper limb (Fig. 5.60). This type of injury is due to either a fall onto the side of the shoulder or throwing the arm into an extended and externally rotated position to break a fall. The force therefore transmits to the weakest anatomical structure, i.e. the metaphysis, epiphysis and growth plate (Ogden 2000, 466). A 1.5-year old (skeleton 145) with skeletal lesions indicative of rickets and thalassaemia also exhibited a fracture callus at the distal end of the right radial diaphysis (Fig. 5.61). There are several mechanisms that this fracture may have arisen from. Looser’s zone has to be considered as a pathological pseudo-fracture in the distal radius due to rickets (Aufderheide and Rodriguez-Martin 1998, 307; Keller and Barnes 2008). However, these pseudo-fractures do not present angulation or displacement (Keller and Barnes 2008). Another possible interpretation may be a torus fracture with buckling of the cortex or a greenstick fracture with the cortex intact on the ulnar aspect albeit only minimal (Ogden 2000, 615-617). Fractures of the distal radius mostly occur due to a fall onto an outstretched arm (Ogden 2000, 617). Although this child was only around 18 months at the time of death it would have started walking (Lewis 2007, 6), and was therefore at increased risk of falling over.

Figure 5.60. Humeral fracture. Left humerus (right) with angulation and changes in proximal and distal epiphyses secondary to mid-shaft fracture. Right humerus (left) for comparison. From Butt Road, Colchester, skeleton 595. (with permission from Colchester and Ipswich Museums)

a, b,

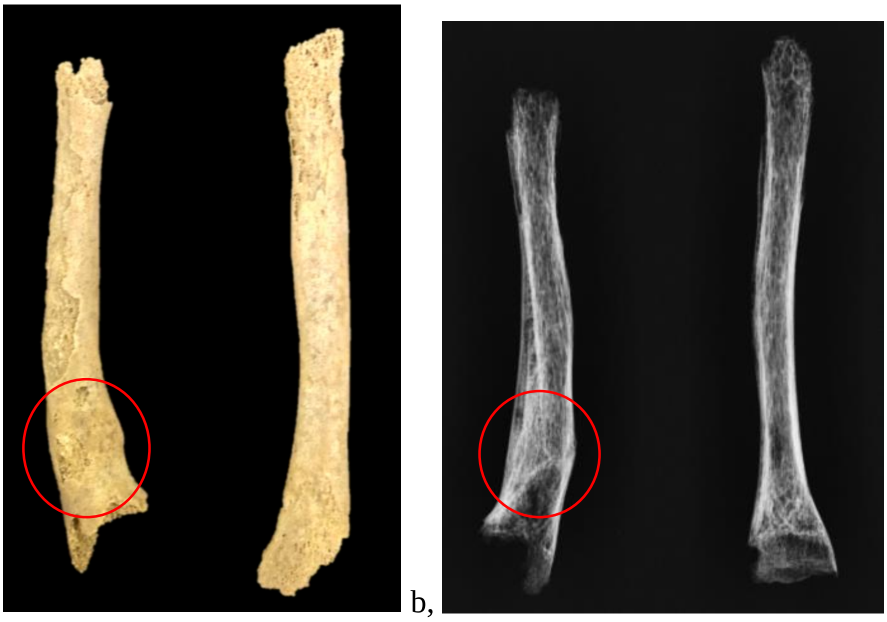


Figure 5.61. Right radius (left) with fracture at the distal epiphysis. Anterior in a, medial in b. Note the new bone formation anteriorly. Left radius (right) for comparison. This is also a suspected thalassaemia and vitamin D deficiency case. From Butt Road, Colchester, skeleton 145. (with permission from Colchester and Ipswich Museums)

A possible case of trauma to the left ulna was also identified in skeleton 299 at Bath Gate, Cirencester with a mean dental age of around 14 years. The trochlear surface of the left ulna displays irregularity on the joint surface and extends anteriorly and medially at the margins, and is osteophytic in appearance. The coronoid process is almost completely obliterated. The radial notch is unaffected (Fig. 5.62). The left radius and humerus show no pathological changes. Dislocation of the elbow may be a possible aetiology behind the changes in the ulnar head, however these would also yield morphological changes in the radius (Nikitovic et al. 2012). An olecranon or coronoid fracture may also be an underlying cause (Ogden 2000, 575-582). The anterior radiograph in Figure 5.63 does not show a recognisable fracture line, but a slightly more radio-opaque area at the coronoid process. Fractures to the coronoid process are usually small, but can result in dislocation of the elbow (Ogden 2000, 580). Perhaps the morphological changes in the left ulna of skeleton 299 are a remnant of a fracture to the coronoid process in younger years. Alternatively, trauma to the physis underneath the articular cartilage of the coronoid process may have yielded morphological changes and osteophytic lipping (Ogden 2000, 567). Although a specific fracture mechanism cannot be assigned as no specific fracture pattern could be identified, we know that forearm fractures in children are not uncommon, and frequently associated with falls (Ogden 2000, 574-575).

a,  b, 

Figure 5.62. Proximal left ulna (b) with enlarged joint surface and osteophytic lipping. Right ulna for comparison (a). Periosteal reaction on both shafts. From Bath Gate, Cirencester, skeleton 299. (with permission from Corinium Museum)

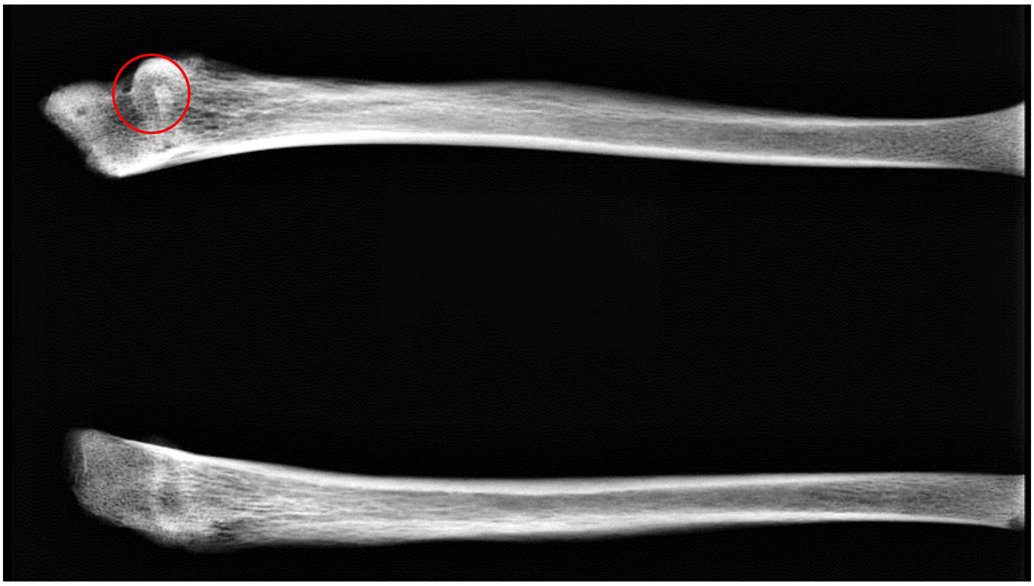


Figure 5.63. Anterior radiograph of left (top) and right ulna. No fracture line is evident in the proximal left ulna but an area of increased cortical density at the coronoid process. From Bath Gate, Cirencester, skeleton 299. (with permission from Corinium Museum)

5.3.4.11. Dislocation

The 10 year-old from Queensford Farm/Mill with slipped capital femoral epiphysis (SCFE), or alternatively Perthes disease (skeleton 22/205, Fig. 5.64) in the right femoral head has not been reported previously. The site skeletal report in Chambers (1987) does however mention that this individual displays abnormal fusion of the right femoral head.

This child would have been affected by severe pain, limited weight bearing ability of the right lower limb and restricted motion of the right leg and hip (Ogden 2000, 868). SCFE and Perthes disease have similar and corresponding bony changes which may not be distinguishable from one another. Both conditions are relatively rare, mainly unilateral, affect boys more frequently than girls and usually begin between the ages of 5-9 years in Perthes disease, and 10-17 years in SCFE (Loder 1996; Ortner 2003, 346-347; Lehmann 2006). Ogden (2000, 868) stated that SCFE results from a pre-exisiting condition of chronic mild slips leading to greater displacement over time, or arise from dislocation or traumatic injury to the hip. Perthes disease is however associated with a limited blood supply that was probably a result of trauma to the area (Ortner 2003, 346). Previously reported Romano-British cases include Clough and Boyle (2010, 373) who described Perthes disease in a male adult skeleton at Lankhills, Winchester. No references to either SCFE or Perthes disease in Romano-British non-adults are available, which may be expected as this is an infrequent skeletal pathology.

Figure 5.64. Dislocation of the femur. Right femur (bottom) with infero-posterior displacement of the femoral neck and proximal metaphysis as a result of unilateral slipped capital femoral epiphysis or Perthes disease. From Queensford Farm/Mill, skeleton 22/205. (with permission from Oxfordshire Museums Service)

5.3.4.12. Embryotomy

No incidence of sharp-force trauma, such as embryotomy has been recorded, although it hs been reported in two instances in Roman Britain. Cut marks throughout on a perinate at Poundbury Camp indicate dismemberment, which follows the procedure for embryotomy described by Soranus (Lewis pers. comm.; Molleson and Cox 1988; Roberts and Cox 2003, 160-161; Redfern and Gowland 2012). Cut marks on the right femur of a perinatal infant from Yewden Roman villa in Hambleden, Buckinghamshire, are also indicative of embryotomy being performed on a rural site (Mays et al. 2014). The absence of perimortem cuts on the current perinatal sample may be a result of burial practices, where babies that had to be dismembered during obstetric difficulties were buried elsewhere, or cut marks on the skeleton are absent.

5.3.4.13. Congenital disease

Congenital anomalies recorded include costal fusion, malformations of the spine, and a possible case of mild hydrocephalus according to the criteria set out in Aufderheide and Rodriguez-Martin (1998, 69) and Ortner (2003, 460, 463). Seven cases of congenital defects have been found in the primary study sample, two of which occurred in non-adults from Cannington and have been reported previously by Brothwell et al. (2000). A 16-year old from Cannington (skeleton 176) presents the possible case of mild hydrocephalus. Brothwell et al. (2000, 235-237) have previously identified this individual. The cranium is enlarged and exhibits a slightly more prominent parietal boss, with areas of thinning and bulging throughout the cranial elements. There are localised foci of thinning of the inner table in the frontal bone with exposure and thinning of the underlying trabecular structure. Hydrocephalus can be both congenital and acquired in origin, although it is unlikely that more severe cases of congenital hydrocephalus are recognisable in the archaeological record as this would have caused obstetric difficulties to both the mother and child (Roberts and Manchester 2010, 53). Viral infections, trauma or tumours may lead to hydrocephalus in childhood by causing accumulation of cerebrospinal fluid in the cranium (Ortner 2003, 456). Although it is not possible to identify the cause of the mild hydrocephalus in skeleton 176, it may be inferred that the accumulation of fluid in the skull may have presented physical disabilities and subnormal mental development (Roberts and Manchester 2010, 53).

Three cases of fused ribs have been identified. A perinate of 37 weeks gestation from Cannington (skeleton 429) showed fusion of a right rib fragment with no other sign of skeletal pathology, although the individuals was poorly preserved and fragmentary. This case was reported previously by Brothwell et al. (2000, 203). Although uncommon, Guttentag and Salwen (1999) class bifid ribs, and rib fusion or bridging as normal variants which are only rarely of clinical significance. An infant from Bath Gate (skeleton 355) also had one bifid left rib. Some ribs exhibit porosity of the cortex and fraying at the sternal ends, there is also evidence for osteopenia in the pelvis and long bones. The skeletal changes observed are not widespread enough to pinpoint a particular nutritional deficiency but may be the result of a generally poor nutritional status. Bifid ribs also occur in Gorlin Basal Cell Nevus Syndrome, which also involves macrocephaly, mandibular dysplasia and other rib abnormalities such as fusion, agenesis or altered shape (Glass et al. 2002). None of these additional skeletal lesions have been recorded in skeleton 429 from Cannington and 355 from Cirencester, and their rib anomalies may therefore just be a normal congenital variant, rather than a pathological manifestation of a more widespread congenital disorder. A 14-year old female from Baldock (skeleton Bal15’94 2025) exhibited fusion of right ribs 2 and 3, with periosteal new bone on the visceral aspect of left rib shafts. Both the atlas and axis showed osteochondritis dissecans on the left superior articular facets. The teeth were marked by exceptionally heavy wear on the lingual aspects of the maxillary incisors and labial surface of the mandibular incisors. In most instances fusion or bridging of ribs is uncommon yet a normal developmental variant (Guttentag and Salwen 1999). It may however also be one of the manifestations of Gorlin syndrome (Glass et al. 2002), although its accompanying skeletal changes have not been observed in this individual. Fused ribs can cause restriction of the chest wall expansion, as well as scoliosis which can only be rectified surgically (Glass et al. 2002). No signs of scoliosis were found in the spine of Bal15’94 2025, and we cannot be sure whether or not the fused ribs interfered with the expansion and contraction of the thorax. However new bone formation on the pleural aspect of the left ribs indicates a respiratory infection of unknown origin, potentially related to restricted movement. It cannot be ascertained if this adolescent female suffered from several different conditions, or whether the manifestations of costal fusion, circulatory and infectious disease are part of a more widespread congenital condition. It can also not be determined whether Bal15’94 2025 suffered from any physical symptoms associated with the costal fusion or potentially a more widespread congenital condition.

Three individuals displayed anomalies of the spine. A 12-year old from Bath Gate (skeleton 314) displayed incomplete union of the right neurocentral junction in the atlas and the right dentoneural and neurocentral junctions in the axis. There is slight asymmetry in the atlas, with the right arch displaced anteriorly. The axis is marked by a slight left lateral tilt of the dens and infero-lateral sloping of the right articular facet. Lustrin et al. (2003) identified trauma as a cause for displacement and subluxation, but skeleton 314 does not display fracture calluses on the atlas or axis. No other gross skeletal changes were observed in this individual. It may be assumed that the incomplete union of these elements was asymptomatic and possibly due to delayed epiphyseal fusion, or cleft arches (Smoker 1994). Alternatively, Hosalkar et al. (2008) described a dysmorphic atlas as a congenital anomaly of the upper thoracic spine, which may have affected skeleton 314 and led to secondary morphological changes in the axis. The degenerative and congenital changes observed in skeleton 277 from Cannington have also been reported previously by Brothwell et al. (2000, 203). The osteophytic lipping in the thoracic and lumbar spine of skeleton 277 from Cannington is likely to have been degenerative in origin. This 16-year old female also exhibited a sacral and sternal cleft, as well as changes in the occipital condyles and atlas, which may be classified as a dysmorphic atlas (Hosalkar et al. 2008). The sternal defect may simply be due to failure of union between the bilateral ossification centres of the sternum and not present any health implications (Ortner 2003, 471). Similar to the sternal cleft, the sacral cleft may also present an asymptomatic congenital anomaly that may be classed as a non-metric trait (Berry 1975). Lastly, a 15.5-year old female from Dunstable (skeleton G/T1284) presented a possible case of thoracic spinal stenosis (Dimar et al. 2008), there is a caveat to the diagnosis however as no measurements of the vertebral canal were taken at the time of recording. Suggesting spinal stenosis is therefore a reminder to re-record and investigate this individual further. Stenosis in the thoracic spine may lead to compressive myelopathy and eventually partial paralysis of the lower limbs. Thoracic stenosis can arise from a number of congenital disorders, as well as a range of other conditions such as Scheuermann’s disease, degenerative disc disease or ossification of spinal ligaments (Chang et al. 2001).

5.4. THE PRIMARY STUDY SAMPLE IN COMPARISON WITH IRON AGE AND POST-MEDIEVAL DATA

Comparison with other palaeopathological studies investigating child health in Iron Age Britain and the post-medieval period was sought. This approach allows for an evaluation of the patterns seen in the palaeopathology of Romano-British non-adults. Subsequently, similarities and differences between the prevalence of stress markers and pathological lesions in the Romano-British sample and those from other time periods may aid in contextualising ill-health under Roman rule.

5.4.1. Palaeopathology across Roman Britain and Late Iron Age Dorset

Redfern (2007) and Redfern et al. (2012) provide data for non-adults in Late Iron Age (LIA) Dorset as a regional perspective. The age categories used in Redfern (2007) and Redfern et al. (2012) could not be replicated precisely but were adhered to as accurately as possible to allow for comparison (see A7.1 and A7.2 in Appendix VII). The adolescent age category comprises of individuals aged to 12-20 years old, which could not be replicated in the primary study sample of Roamno-British non-adults with a cut-off age of 17.0 years.

Crude prevalence rates of enamel hypoplasia were generally lower in the Iron Age children from Dorset (Fig. 5.65). Periosteal new bone formation in the Late Iron Age children was reported at lower rates than in major urban and rural children from the Roman period (Fig. 5.66). Similarly, cribra orbitalia was reported at lower frequencies in the Iron Age non-adults (Fig. 6.7). The crude prevalence rate for rickets was highest in the children aged 0-3 years from Iron Age Dorset at 11.1% (Fig. 5.68). However, this result is influenced by sample size, as only one non-adult aged 0-3 years was affected out of a total of nine individuals within this age group (Redfern et al. 2012).

In 12-20-year olds, the rate of caries per individual with dentition is highest in the Late Iron Age at a rate of 40.0%. Caries in 3-12-year olds from Iron Age Dorset at CPR 16.7% is higher than the rate observed for children of this age group in rural Romano-British settlements (n=0), and similar to the one seen in children from major urban settlements (CPR 17.4%) (Fig. 5.69).

Statistical analysis was not performed as some of the crude prevalence rates were reported as percentages only in Redfern (2007) and numbers of affected as opposed to total individuals per cohort were not attainable (see A7.3 in Appendix VII). Some of the sample sizes, for example for rickets in Late Iron Age children were also too small to warrant meaningful statistical analysis and results.

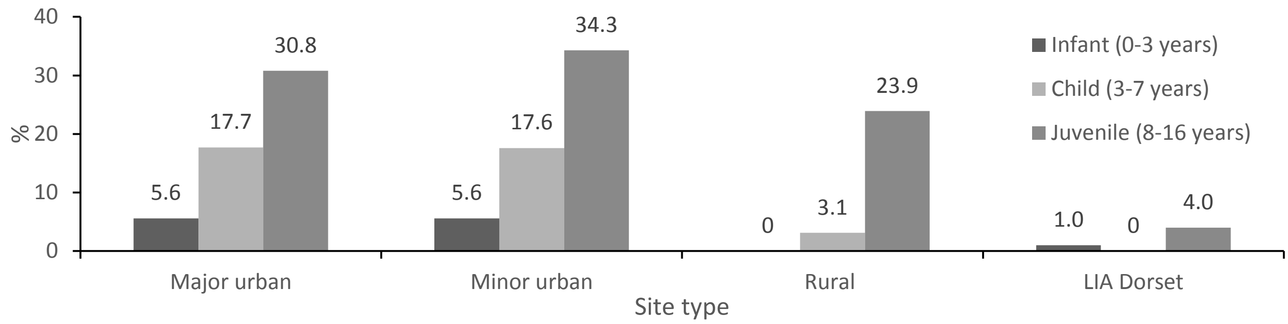


Figure 5.65. Crude prevalence rates of enamel hypoplasia in Romano-British and Late Iron Age children (from A7.1 and A7.3 in Appendix VII)

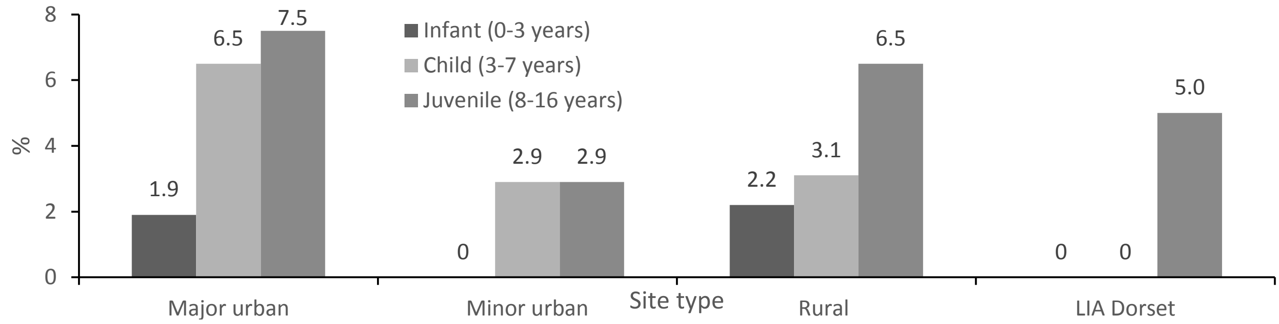


Figure 5.66. Crude prevalence rates of periosteal new bone formation in Romano-British and Late Iron Age children (from A7.1 and A7.3 in Appendix VII)

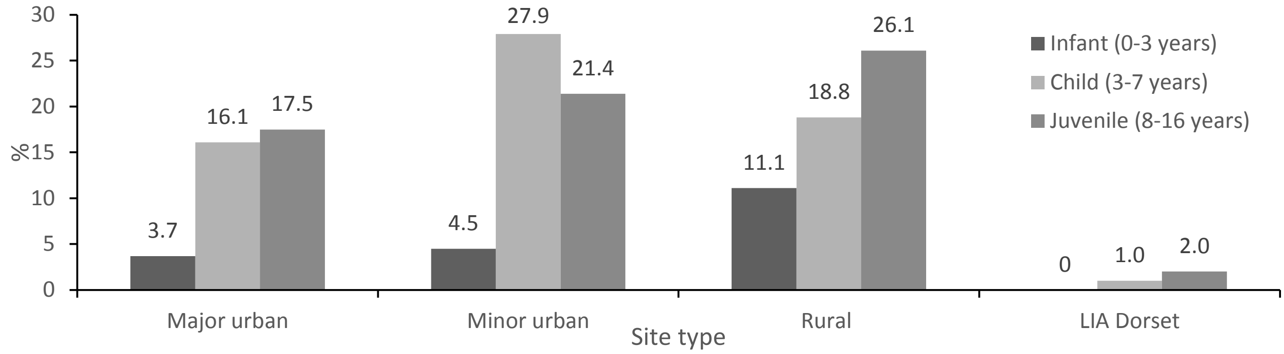


Figure 5.67. Crude prevalence rates of cribra orbitalia in Romano-British and Late Iron Age children (A7.1 and A7.3 in Appendix VII)

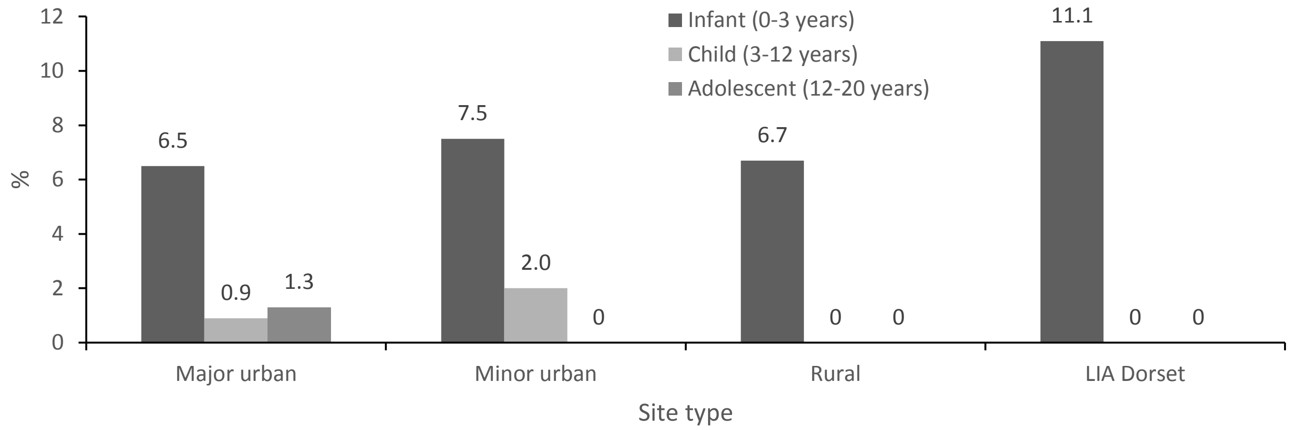


Figure 5.68. Crude prevalence rates of rickets in Romano-British and Late Iron Age children (from A7.2 and A7.4 in Appendix VII)

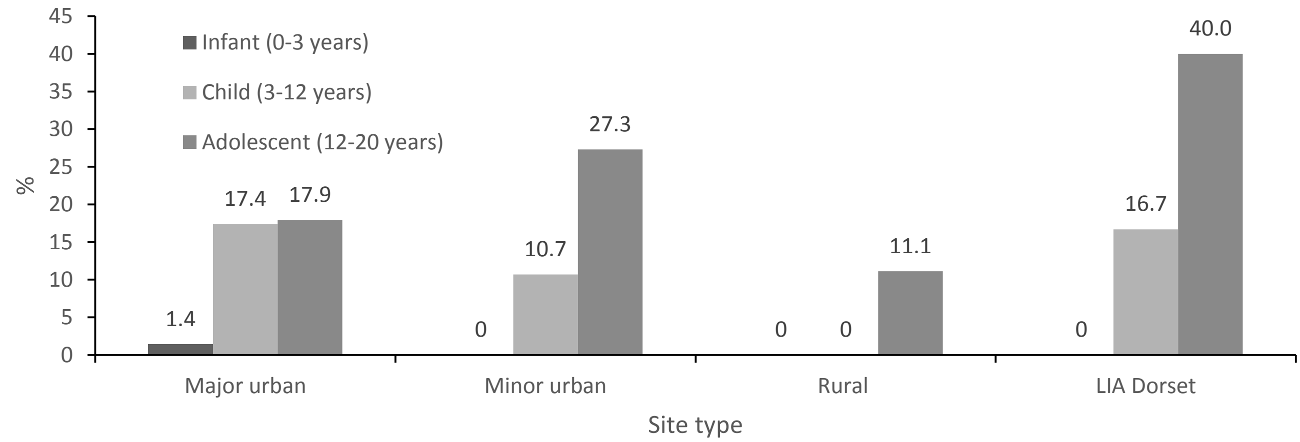


Figure 5.69. Crude prevalence rates of caries in Romano-British and Late Iron Age children (from A7.2 and A7.4 in Appendix VII)

5.4.2. Palaeopathology across Roman Britain and at Christ Church, Spitalfields

Post-medieval data for stress indicators and other pathological lesions was taken from Lewis (2002c). The cemetery dates to the later 18th and first half of the 19th century, with parish records stating a middle to upper class background of the deceased adults (Lewis 2002b, 32).

The true and crude prevalence rates for pathological lesions and stress markers at Christ Church, Spitalfields are tabulated in A7.5 and A7.6 (in Appendix VII). Figure 5.70 presents the different prevalence rates of stress markers and metabolic disease in the Romano-British and post-medieval children. Periosteal new bone formation (CPR) was the only lesion that occurred less frequently in the children from Spitalfields, as all other lesions were elevated in this sample compared to Romano-British children from the different site types. The crude prevalence rate of enamel hypoplasia in the London sample is in between the prevalence reported for the major urban and minor urban Roman period children. Cribra orbitalia was at least twice as frequent in the post-medieval cohort than in any of the Romano-British groups, this distribution is statistically significant (X^2=65.94, p<0.001, d.f.=3). A similar distribution is also apparent in the crude prevalence rates of metabolic disease (rickets and scurvy), which is also significant (X^2=16.58, p<0.001, d.f.=3). Rickets was expected at higher frequencies in the post-medieval period, which was also validated statistically (X^2=20.46, p<0.001, d.f.=3) (Fig. 5.70).

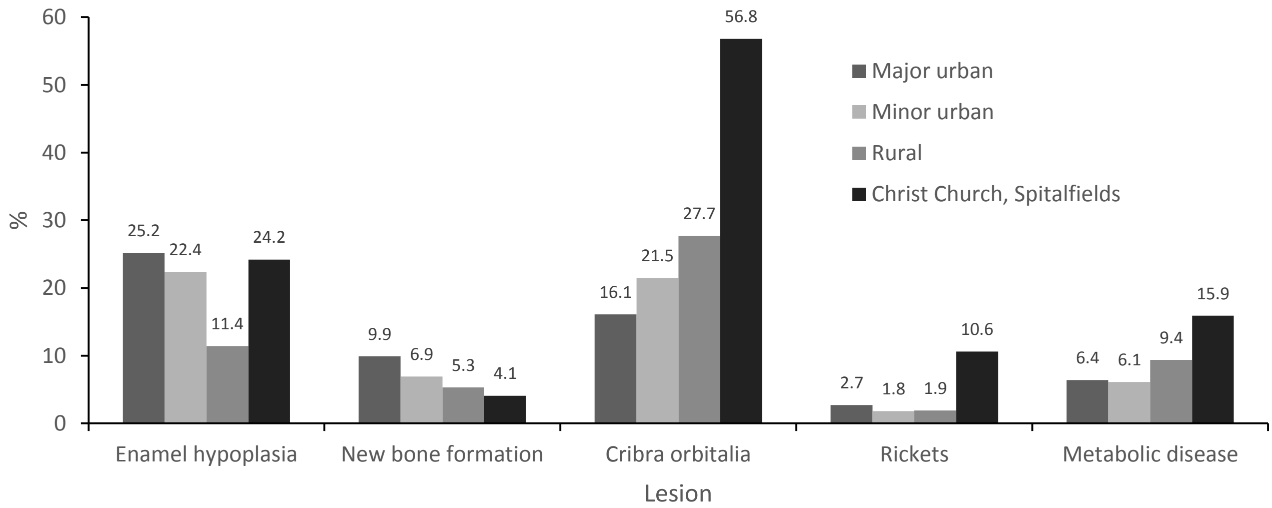


Figure 5.70. Distribution of lesions between the Romano-British sample and Christ Church, Spitalfields (from A7.5-A7.7 in Appendix VII; TPR for cribra orbitalia, all other CPR)

The use of similar age groups in Lewis (2002b,c) and the current studies allowed for comparison of prevalence rates of cribra orbitalia (TPR), enamel hypoplasia (CPR), new bone formation (CPR) and metabolic disease (CPR) according to skeletal age.

Enamel hypoplasia was reported at higher rates in the Spitalfields children aged 0.6-2.5 years, and 10.6-14.5 years, compared to the Roman sample. The relationship is reversed for the remaining age groups, however it is mainly the major urban and minor urban non-adults with enamel hypoplasia who exhibit higher crude prevalence rates than the sample from post-medieval London (Fig. 5.71). In 6.6-10.5-year olds, sub-periosteal new bone formation occurred most frequently in the rural Romano-British children. As outlined in Figure 5.72, there is a great variance in the distribution of individuals reported with sub-periosteal new bone formation. Apart from 10.6-14.5-year olds, crude prevalence rates were consistently higher in the Romano-British cohort. Throughout all age groups, cribra orbitalia was most frequent in the children from post-medieval London. Rural Romano-British children attained the same rate of cribrotic lesions in 6.6-10.5-year olds (TPR 66.7%) than children from Christ Church, Spitalfields, and an almost similar rate in 0.6-2.5-year olds at TPR 50.0% versus TPR 53.7% (Fig. 5.73). Figure 5.74 includes individuals with vitamin C and/or D deficiency, as no individuals with scurvy were reported from Spitalfields, but nine individuals were presented as having either rickets, scurvy, or both (see A7.6 in Appendix VII). Up until the age of 2.5 years old, the children from post-medieval London were reported with higher rates of metabolic disease than the Roman sample. However, Romano-British infants under six months old from minor urban cemeteries exhibit almost similar rates of metabolic disease than those from Spitalfields (CPR 16.7% versus CPR 17.5%). However, we have to remember the caveats of identifying metabolic disease in neonates and young infants, which limits the interpretation of this pattern (see section 7.1). In 0.6-2.5-year olds, the frequency of metabolic disease in the rural Romano-British cohort is only marginally less than in the post-medieval sample, at CPR 20.5% as opposed to CPR 21.9%. From 2.6 up until 14.5 years old, metabolic disease was most prevalent in rural Romano-British children, although vitamin C/D deficiencies were overall declining with increasing age in children of the Roman and post-medieval period (Fig. 5.74).

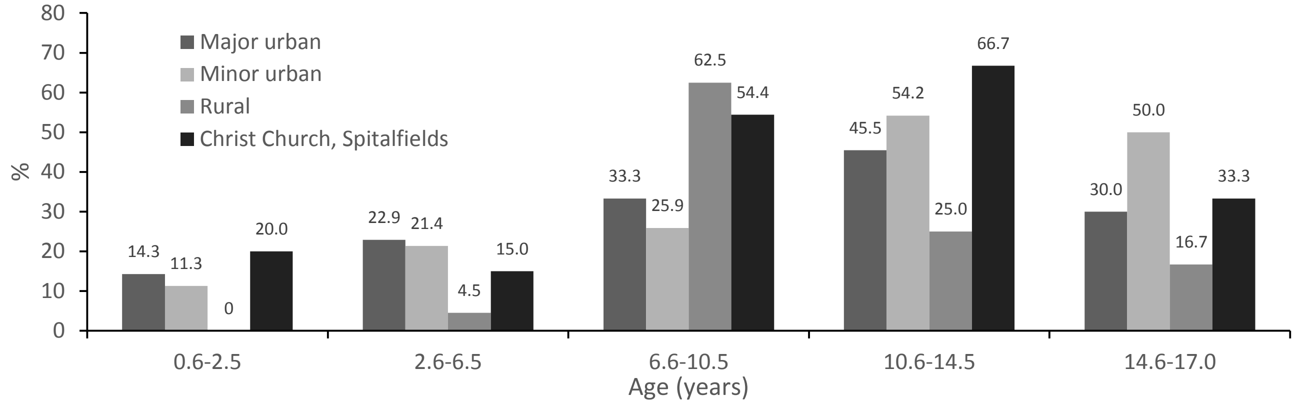


Figure 5.71. Crude prevalence rates of enamel hypoplasia in Romano-British and post-medieval non-adults (from A7.5 and A7.7 in Appendix VII)

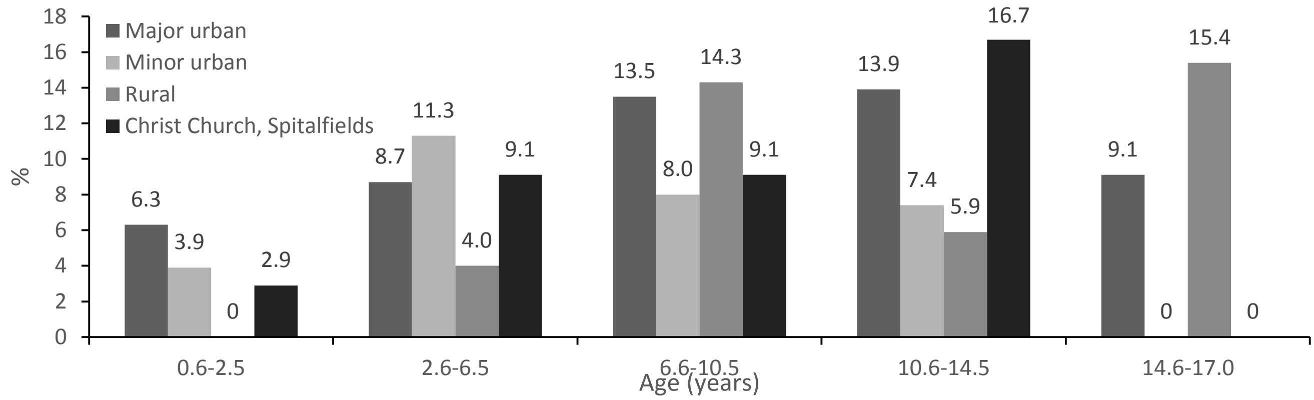


Figure 5.72. Crude prevalence rates of new bone formation in Romano-British and post-medieval non-adults (from A7.5 and A7.7 in Appendix VII)

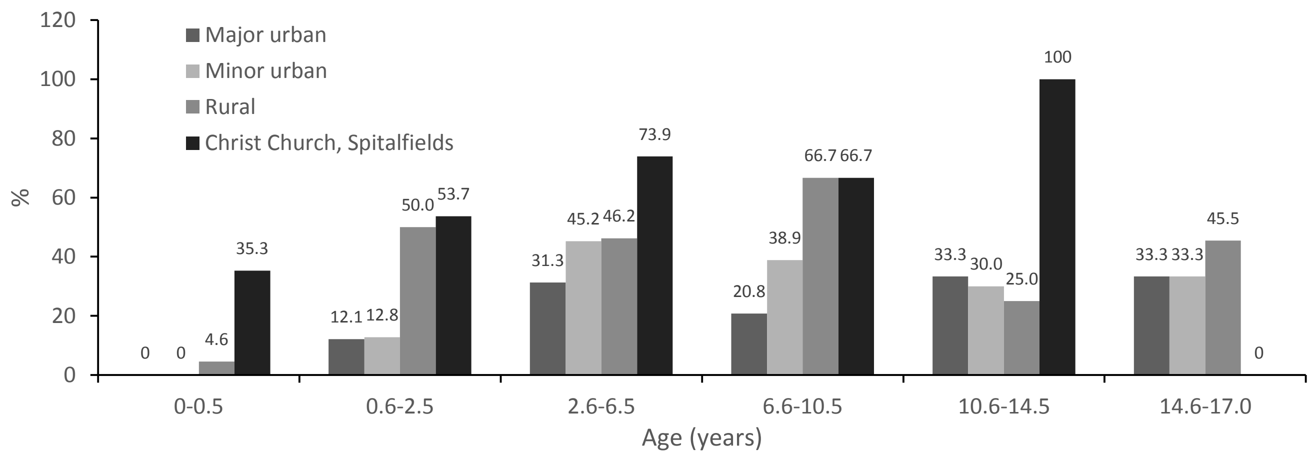


Figure 5.73. True prevalence rates of cribra orbitalia in Romano-British and post-medieval non-adults (from A7.5 and A7.7 in Appendix VII)

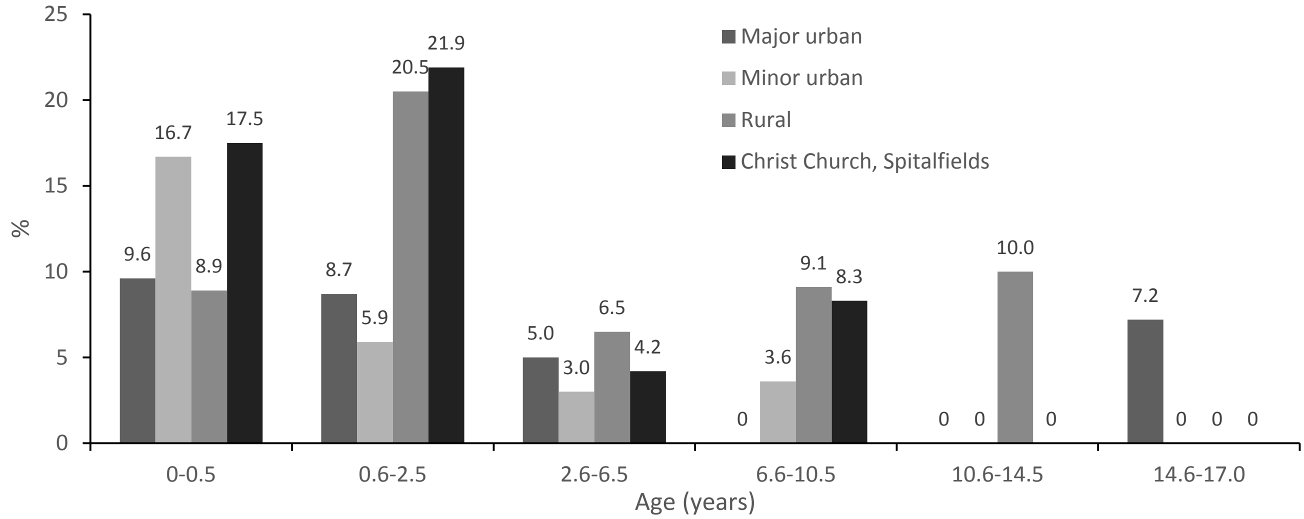


Figure 5.74. Crude prevalence rates of metabolic disease in Romano-British and post-medieval non-adults (from A7.6 and A7.7 in Appendix VII)

Figure 5.75 presents the crude prevalence rates of stress indicators, and skeletal and dental lesions in non-adults across all three time periods. The Romano-British rates reflect the averages for all sites within the primary study sample. The rate of cribra orbitalia is based on individuals with at least one orbit and the rate of enamel defects is per individual with dentition. Unfortunately, Redfern (2007) does not provide summary data for all age groups for cribra orbitalia, enamel hypoplasia and new bone formation, therefore no crude prevalence rates for the total Late Iron Age sample could be included. The graph demonstrates an increase in metabolic disease and caries from the Iron Age to the Roman period, with a peak in metabolic disease in the post-medieval children.

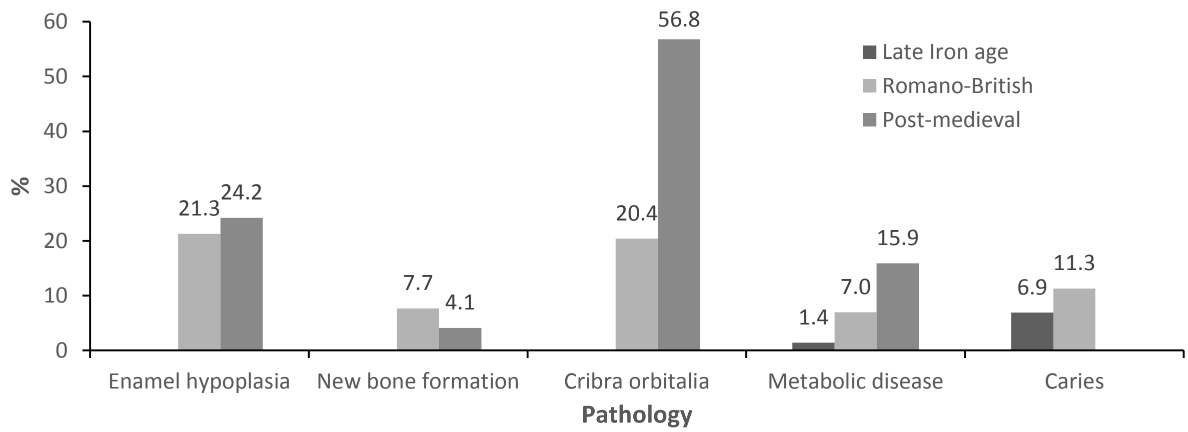


Figure 5.75. Summary of crude prevalence rates in Late Iron Age, Romano-British and post-medieval non-adults (TPR for cribra orbitalia)

CHAPTER 6. RESULTS II - FUNERARY TREATMENT AND PALAEOPATHOLOGY

This chapter is an appraisal of funerary treatment and palaeopathology of Romano-British children. This approach was sought to investigate whether differential treatment in death corresponded with compromised health during life, in an attempt to integrate the evidence of both palaeopathology and funerary archaeology (Roberts et al. 1989). Funerary treatment may relate to 'Christian' as opposed to pagan beliefs, high or low status of the deceased, and the amount of care attributed to the burial (Petts 2004). The decision-making behind burial is a carefully thought out process, and inequalities in health may translate into the burial record (Parker Pearson 2003, 124). How burials were laid out or furnished may be a reflection of the status or sociocultural identity of the community these children were buried in (Parker Pearson 2003, 78-81). It is therefore of interest to explore whether patterns of stress and disease differ between groups, such as locals or 'others', or high- and low-status burials. The results are presented here, with a subsequent discussion of the findings.

Burial information was retrievable for 740 of the 953 non-adult individuals recorded for the primary study sample from 15 sites, including data on grave alignment, the location of the burial within the cemetery, the positioning of the body in the grave, and the presence or absence of grave goods. The results listed here are a brief consideration of palaeopathology in relation to burial characteristics, separate from discussing skeletal and dental pathology in detail in chapter 7. Since late Romano-British burial would have largely followed a standard paradigm of east-west alignment, supine body position and no or only few grave goods in an organised cemetery, deviations from this normative burial practice were of interest (Philpott 1993a). Distinct rites may have been practised in adjacent areas of the cemetery, marking distinct burial groups which may have served as sociocultural markers (Petts 2004; Turner 2004). However, we have to acknowledge the effects of local topography and settlement or cemetery features such as roads, ditches or walls.

6.1. ALIGNMENT

A total of 570 burials yielded information on burial alignment from the site report or excavation records. The majority of burials were placed along the east-west axis (71.4%, n=407) (Table 6.1). Overall, north-south alignment was the second most frequent orientation for the total sample (13.0%, n=74). In major urban cemeteries, alignment follows the same pattern with east-west most frequent (65.9%, n=176) followed by north-south (22.9%, n=61).

In minor urban burial grounds, east-west alignment was also most frequent (57.6%, n=72) however more graves were aligned northeast-southwest (30.4%, n=38) than strictly north-south (7.2%, n=9). Rural burials were mainly oriented east-west (89.3%, n=159), followed by northeast-southwest (8.4%, n=15).

Table 6.1. Burial alignment by site type

	Major urban		**Minor urban**		**Rural**		**Total**	
	n	*%*	*n*	*%*	*n*	*%*	***n***	***%***
E-W	176	65.9	72	57.6	159	89.3	**407**	**71.4**
N-S	61	22.9	9	7.2	4	2.3	**74**	**13.0**
NE-SW	11	4.1	38	30.4	15	8.4	**64**	**11.2**
SE-NW	19	7.1	6	4.8	0	0	**25**	**4.4**
Total	**267**		**125**		**178**		**570**	

% of cohort by site type

Since alignment was not uniform across the cemeteries, the distributions of cribra orbitalia, enamel hypoplasia, metabolic disease, infections of non-specific origin and dental disease along the east-west and north-south axes were tested. East-west was compared to north-south and the other planes combined (Fig. 6.1 and Table 6.2). Only weak statistical differences have been observed that are not significant at the 99.9% level.

For the total sample both cribra orbitalia (25.8%, n=58) and infections of non-specific origin (22.8%, n=69) occur at higher rates in individuals buried along the east-west axis (X^2=5.12, p<0.05, d.f.=1; X^2=3.95, p<0.05, d.f.=1). Rates of pathology in the major urban and rural cohorts did not differ statistically according to burial alignment. In minor urban cemeteries, those buried east-west exhibited higher rates of infections of non-specific origin (31.8%, n=21; X^2=8.54, p<0.01, d.f.=1). In contrast, the minor urban non-adults deviating towards the north-south plane displayed more instances of dental disease (23.7%, n=9; X^2=4.09, p<0.05, d.f.=1) (Fig. 6.1 and Table 6.2).

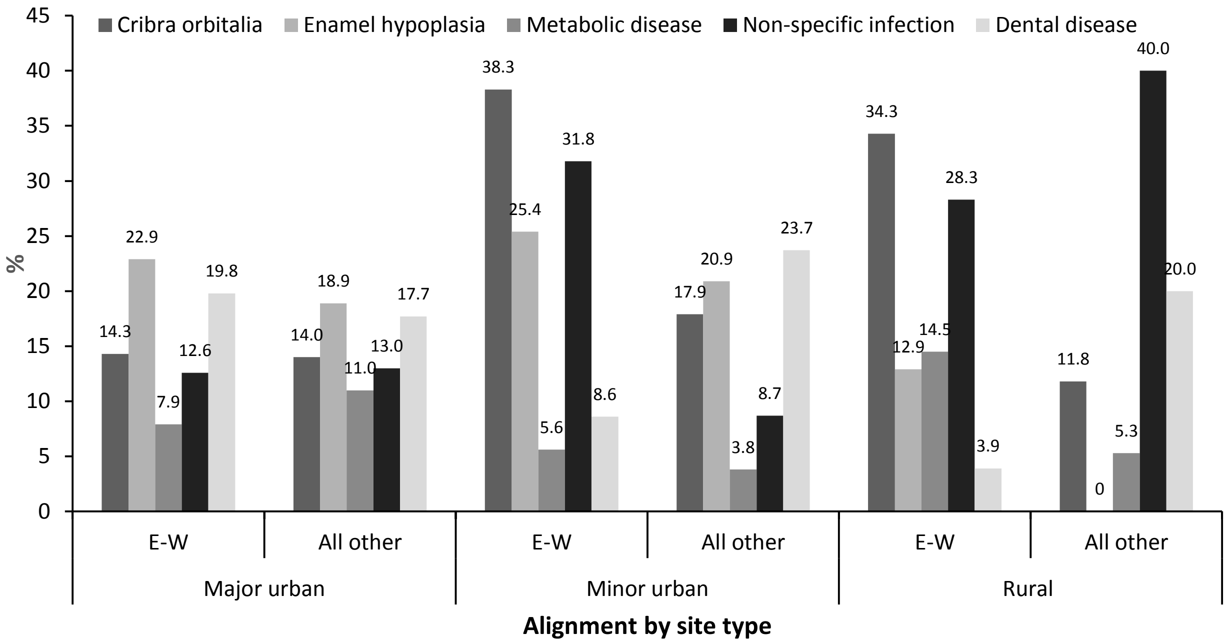


Figure 6.1. Burial alignment and pathology

6.2. BURIAL LOCATION AND FEATURE

Unusual burial locations or features outside of the main cemetery are presented in Table 6.3. In major urban cemeteries, non-adults were almost exclusively buried in the main cemetery area (335 out of 336 inhumations with burial location). The exception was one perinate at Victoria Road East, Winchester (skeleton VRE416), who was recovered from a pit and showed evidence for vitamin D deficiency. The 17 individuals from minor urban sites that have been buried in ditches, wells and cesspits are exclusively from Roman Dunstable. The two individuals recovered from cesspits are a 36-week old foetus and a perinate. The four individuals buried in wells range from birth to eight years old. Skeleton BN2 with an average age of eight years old displayed enamel hypoplasia and osteochondritis dissecans on the superior articular facets of the cervical vertebrae. The three additional individuals found in wells were a 3-month old infant (skeleton BN/T1329), a perinate (skeleton BM/T1324), and a neonate (skeleton BL/T1324). The latter showed an enlarged trabecular structure of the long bones, with slight thinning of the cortical bone, and increased lightness, indicative of osteopenia.

Table 6.2. Distribution of lesions by burial alignment

	Major urban				Minor urban				Rural				**Total**			
	E-W		All other		E-W		All other		E-W		All other		**E-W**		**All other**	
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	***n***	***%***	***n***	***%***
Cribra orbitalia	15	14.3	8	14.0	18	38.3	5	17.9	25	34.3	2	11.8	**58**	**25.8**	**15**	**14.7**
Enamel hypoplasia	30	22.9	10	18.9	15	25.4	9	20.9	12	12.9	0	0	**57**	**20.1**	**19**	**18.5**
Metabolic disease	14	7.9	10	11.0	4	5.6	2	3.8	23	14.5	1	5.3	**41**	**10.1**	**14**	**8.6**
Non-specific infection	17	12.6	6	13.0	21	31.8	4	8.7	30	28.3	2	40.0	**69**	**22.5**	**13**	**13.4**
Dental disease	21	19.8	6	17.7	5	8.6	9	23.7	3	3.9	1	20.0	**29**	**12.0**	**15**	**19.5**

% of cohort by site type (see Table 6.1)

A total of 11 non-adults were buried in the ring ditch of the cemetery, their graves were either cut into the ditch or part of the ditch fill (Matthews 1981, 5, 7-11). Three perinates have been deposited as a triple burial (skeletons CH/T1335, CI/T1335, CJ/T1335). Infant burial AR has been deposited on top of another infant burial KK. Two burials were found with grave goods, neonate CE was interred with a bracelet, and an adolescent female of around 15.5 years (skeleton G/T1284) was found with bronze and glass jewellery. This female also suffered from a vertebral pathology. Another female of around 13.5 years (skeleton HH/T1347) was found with cribra orbitalia and occlusal caries on the maxillary molars. The remaining three individuals exhibited no pathological lesions, and include a perinate (skeleton S32), an infant (skeleton BQ/T1332) and a 5-year old (skeleton KK2).

Table 6.3. Burial location by site type

	Major urban	**Minor urban**	**Rural**
Periphery of cemetery	0	0	14
Ditch	0	11	0
Well	0	4	0
Cesspit	0	2	0
Intramural	0	0	42 (2 under eaves)
Pit	1	0	1*
Total	**1**	**17**	**56**

*included in intramural

The 14 rural burials from peripheral areas of a formal cemetery all originate from Cannington, Somerset. The non-adults are aged between 37 gestational weeks up to 13 years. Cribra orbitalia was recorded in two individuals, and enamel hypoplasia in three. An 11-year old (skeleton 514) was found with caries. The foetus of 37 weeks (skeleton 429) exhibited congenital fusion of two true rib shafts. The 42 intramural burials were found at Catsgore and Bradley Hill in Somerset. All of the 19 individuals that have been recorded from the Catsgore skeletal archive were buried within the settlement, and are almost exclusively perinates and infants (four preterm individuals, six perinates, five neonates, three infants and one 3.5-year old).

Fifteen individuals were buried within buildings in rooms associated with living accommodation, or an agricultural function. One neonate (skeleton F224) was buried with shells, and nails indicate a coffin. Two neonates (skeletons F184a and F184b) were found in a disturbed double burial, where F184a was found with pottery fragments and laid out north-south, and F184b laid out west-east. The 3.5-year old (skeleton F346) was buried in a coffin in a slab-lined grave with pottery, to the north of a building that may have served a dwelling purpose, as well as having functioned as a corn-dryer. A disturbed neonate burial (skeleton F564) in a slab-lined grave was also found outside to the west rather than within a building that may have served as living accommodation. Two burials were recovered from under the eaves of two buildings that were probably used for dwelling, a perinate (skeleton F210) and a foetus of 36 weeks gestation (skeleton F443) (Leech 1982). At Bradley Hill, six of the 29 individuals that have been recorded were buried in the main cemetery of the settlement (Leech et al. 1981). These six individuals are aged from infancy to three years. A five-month old, skeleton F132, exhibited lesions indicative of vitamin C deficiency. F123 of around three months of age also showed signs of scurvy, as well as cribra orbitalia, and a healed fracture of the left clavicle. The remaining 23 non-adults have been buried within the settlement in cists and slab-lined graves, and are mainly aged below one year (two preterm individuals, seven perinates, four neonates, five infants). Skeleton F44, a perinate, was buried in a pit, rather than a slab-lined grave. Bones of the hands and feet of an adolescent have also been recorded, as well as four young children below the age of three years. Cribra orbitalia and endocranial lesions were found in a two-year old (skeleton F77). Congenital fusion of the deciduous incisors and cribra orbitalia were recorded in a 1.5-year old (skeleton F87). Signs of non-specific infection were recorded in a three-year old (skeleton F82).

The distribution in major urban burials was not tested as the sample for other burial locations was too small. In the minor urban sample, similar distributions of cribra orbitalia, enamel hypoplasia, metabolic disease, non-specific infection, and dental disease between those buried in the main cemetery and other locations were found (Table 6.4 and Fig. 6.2).

Table 6.4. Distribution of lesions by burial location in the minor urban sample

	Main Cemetery			Other location		
	n	*%*	*N*	*n*	*%*	*N*
Cribra orbitalia	23	25.6	90	1	16.7	6
Enamel hypoplasia	26	23.4	111	1	20.0	5
Metabolic disease	11	6.2	177	1	5.9	17
Non-specific infection	31	26.1	119	0	0	0
Dental disease	12	12.1	99	1	33.3	3

% of cohort

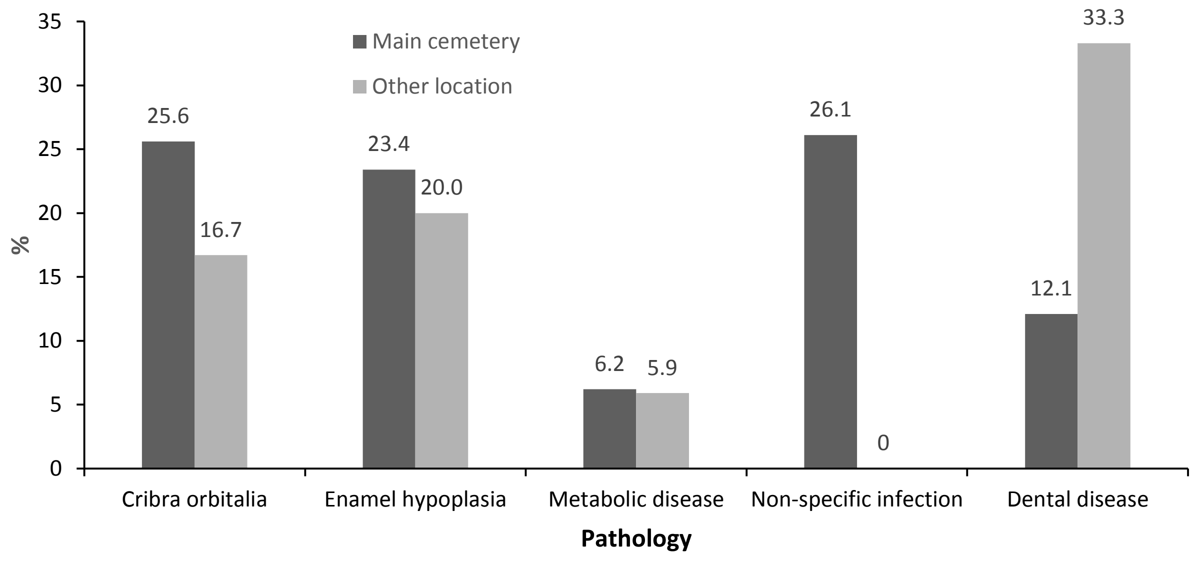


Figure 6.2. Burial location and pathology in the minor urban cohort

In the rural sample, the distributions of cribra orbitalia and metabolic disease between those buried in the formal cemetery and elsewhere warrant attention. However only weak statistical differences were observed, and similar to the observations made regarding lesion distribution and alignment, the results are not significant at the 99.9% confidence level. The rate of cribra orbitalia is higher in the individuals recovered from formal cemetery areas (38.3%, n=23; X^2=8.47, p<0.01, d.f.=1). Similarly, metabolic disease was more frequent in individuals from cemeteries rather than other burial locations (16.4%, n=23; X^2=5.34, p<0.05, d.f.=1) (Table 6.5 and Fig. 6.3).

Table 6.5. Distribution of lesions by burial location in the rural sample

	Main Cemetery			**Other location**		
	n	*%*	*N*	*n*	*%*	*N*
Cribra orbitalia	23	38.3	60	5	12.2	41
Enamel hypoplasia	9	10.8	83	3	12.5	24
Metabolic disease	23	16.4	140	4	5.6	72
Non-specific infection	22	22.5	98	3	13.6	22
Dental disease	2	2.9	69	2	15.4	13

% of cohort

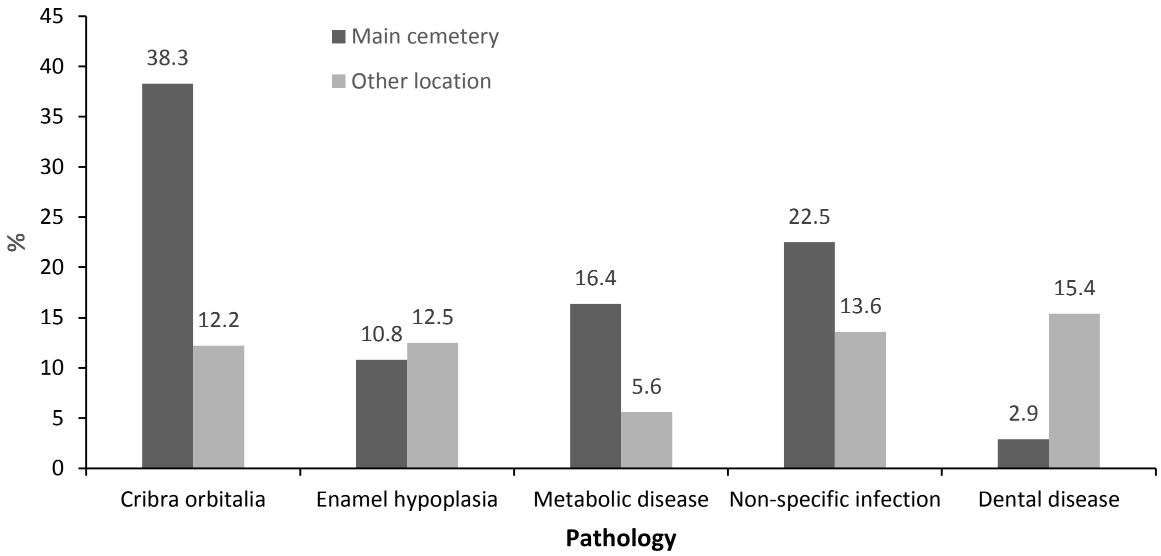


Figure 6.3. Burial location and pathology in the rural cohort

6.3. BODY POSITION

Information on the body position within the grave was available for 510 individuals. The majority were buried in a supine position (85.3%, n=435). Flexed burials have been recorded only in major urban (5.1%, n=26) and minor urban cemeteries (2.6%, n=13). Prone burials have been reported from minor urban cemeteries, from Queensford Farm/Mill and Baldock. Burial 67/246, a 9-year old from Queensford Farm/Mill was buried prone and showed healing cribra orbitalia Grade 3, and a resorptive focus on the anterior aspect of the left scapula inferior to the scapular notch indicative of an infection. At Baldock, the skeleton of a 4-year old (skeleton 5518) with enamel hypoplasia on the unerupted maxillary incisors was buried prone and flexed on the right, along the north-south axis. In the major urban sample, seven prone burials have been reported, three from Bath Gate, Cirencester and four from the cemeteries at Winchester, at Victoria Road West, Hyde Street, Andover Road and Chester Road (Ottaway et al. 2012; Viner and Leech 1982). At Bath Gate, two of the prone burials were also orientated north-south: skeleton 196, of a 3-year old buried within a coffin with jewellery and active Grade 3 cribra orbitalia, and skeleton 251 of a 10-year old with new bone formation on the distal third of the right fibula. The third prone burial is 299, a 14-year old with enamel hypoplasia, a probable respiratory infection and a possible fracture or dislocation of the left elbow. The skeleton of a 12-year old female from Victoria Road West (skeleton VRW63) was recovered prone. The right parietal bone exhibited a very large endocranial sinus by the frontal angle. The trabecular structure is exposed, with thinning and localised destruction of the endocranial bone surface. This sinus may have become enlarged due to drainage of a soft tissue growth, an aneurysm or a fistula (Aufderheide and Rodriguez-Martin 1998, 78; Di Chiro and Doppman 1970; Mullan 1994; Perret and Nishioka 1966). At Hyde Street (skeleton HS8), the remains of a 9-year old have been buried prone. The individual displayed enamel hypoplasia on the permanent incisors and caries in the deciduous dentition. At Andover Road, a 7-year old was buried prone (skeleton AR307). The prone burial at Chester Road (skeleton CHR636) of a 10-year old was aligned north-south as opposed to east-west, and also contained pieces of pot.

6.4. GRAVE GOODS

A total of 64 individuals have been recorded as buried with objects (hobnails have been excluded in this analysis): 13 rural (6.1% of rural individuals), 13 minor urban (3.7% of minor urban individuals) and 38 major urban burials (9.7% of major urban individuals). There is a trend for fewer graves with objects in minor urban burial grounds compared to major urban cemeteries (X^2=10.33, p<0.01, d.f.=1). Objects of personal adornment (jewellery including rings, armlets, bracelets, necklaces, earrings) were most frequent as grave goods in major urban burials (3.1%, n=12). In inhumations from minor urban contexts, pottery (1.4%, n=5) as well as jewellery (1.4%, n=5) were most frequently reported. Within the rural sample, pottery vessels and fragments (3.8%, n=8) were most common (Table 6.6). There was a trend for more burials with personal adornments (3.1%; X^2=8.36, p<0.05, d.f.=2) and coins (2.3%; X^2=8.22, p<0.05, d.f.=2) to be reported from major urban cemeteries.

Table 6.6. Types of graves goods

	Major urban (N=392)		**Minor urban (N=349)**		**Rural (N=212)**	
	n	*%*	*n*	*%*	*n*	*%*
Personal adornment	12	3.1	5	1.4	0	0
Comb	3	0.8	0	0	0	0
Belt/brooch/pin	5	1.3	1	0.3	1	0.5
Knife/blade	1	0.3	0	0	1	0.5
Coins	9	2.3	1	0.3	1	0.5
Pottery/vessels	8	2.0	5	1.4	8	3.8
Miscellaneous	4	1.0	0	0	2	0.9

% of cohort by site type

The distribution of prevalence rates of cribra orbitalia, enamel hypoplasia, metabolic disease, infections of non-specific origin and dental disease was tested between individuals buried with and without grave goods (Tables 6.7 and 6.8). The rates of lesions listed between furnished and unfurnished graves are similar in the urban and rural samples and are not statistically significant (Figs. 6.4 and 6.5). Exceptional cases of pathology within the sample of burials with grave goods comprise of burial 709 from Bath Gate, Cirencester, burial G/T1284 from Dunstable and burial 51b from Cannington. Skeleton 709 at Cirencester with an average age of 13 years was recovered with a coin and a fragmented copper-alloy item. This individual also displayed spinal lesions indicative of brucellosis. Skeleton G/T1284, likely to be an adolescent female, was buried flexed in a ditch with bronze and glass jewellery, and exhibited narrowing of the thoracic vertebral canal, possibly as a result of spinal stenosis (Dimar et al. 2008). The adolescent male from Cannington (skeleton 51b) was buried with a knife in the main site cemetery and was diagnosed with a probable respiratory infection.

Table 6.7. Distribution of lesions in individuals buried with grave goods

	Major urban			**Minor urban**			**Rural**		
	n	*%*	*N*	*n*	*%*	*N*	*n*	*%*	*N*
Cribra orbitalia	4	17.4	23	2	28.6	7	2	25.0	8
Enamel hypoplasia	6	22.2	27	1	12.5	8	1	16.7	6
Metabolic disease	2	5.3	38	1	7.7	13	1	7.7	13
Non-specific infection	4	13.3	30	1	9.1	11	1	20.0	5
Dental disease	5	21.7	23	1	11.1	9	0	0	0

% of cohort by site type

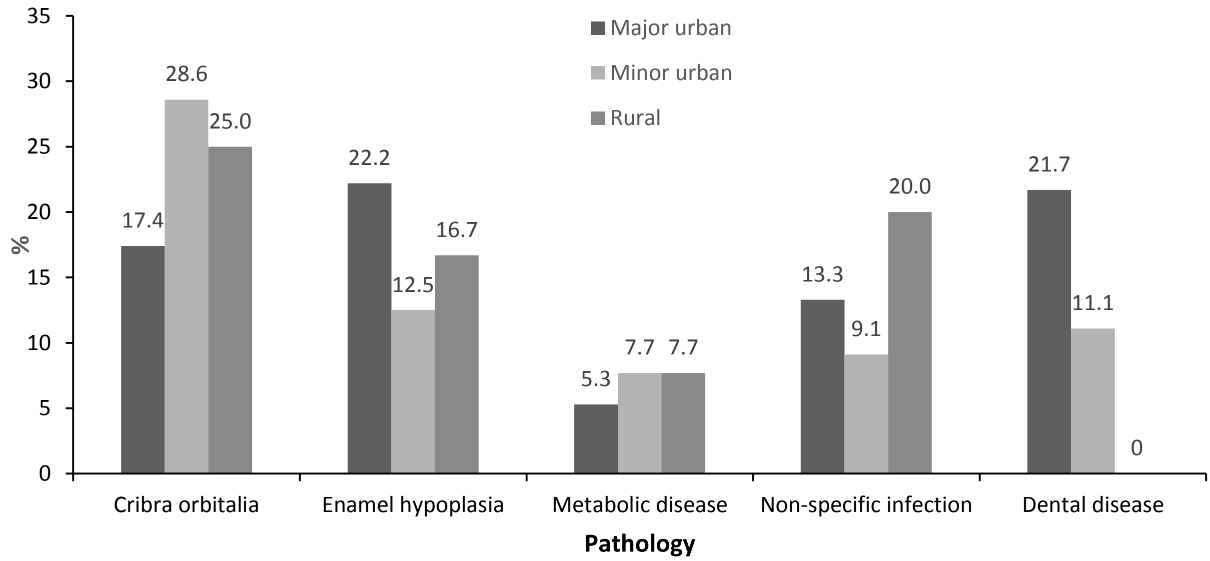


Figure 6.4. Distribution of pathology in burials with grave goods

Table 6.8. Distribution of lesions in individuals buried without grave goods

	Major urban			Minor urban			Rural		
	n	%	*N*	*n*	%	*N*	*n*	%	*N*
Cribra orbitalia	32	16.0	200	38	21.2	179	23	24.7	93
Enamel hypoplasia	48	25.7	187	42	22.8	184	11	11.1	99
Metabolic disease	29	8.5	340	27	8.6	314	26	13.8	189
Non-specific infection	31	13.8	224	50	22.5	222	24	20.9	115
Dental disease	30	18.1	166	24	15.3	157	4	5.2	78

% of cohort by site type

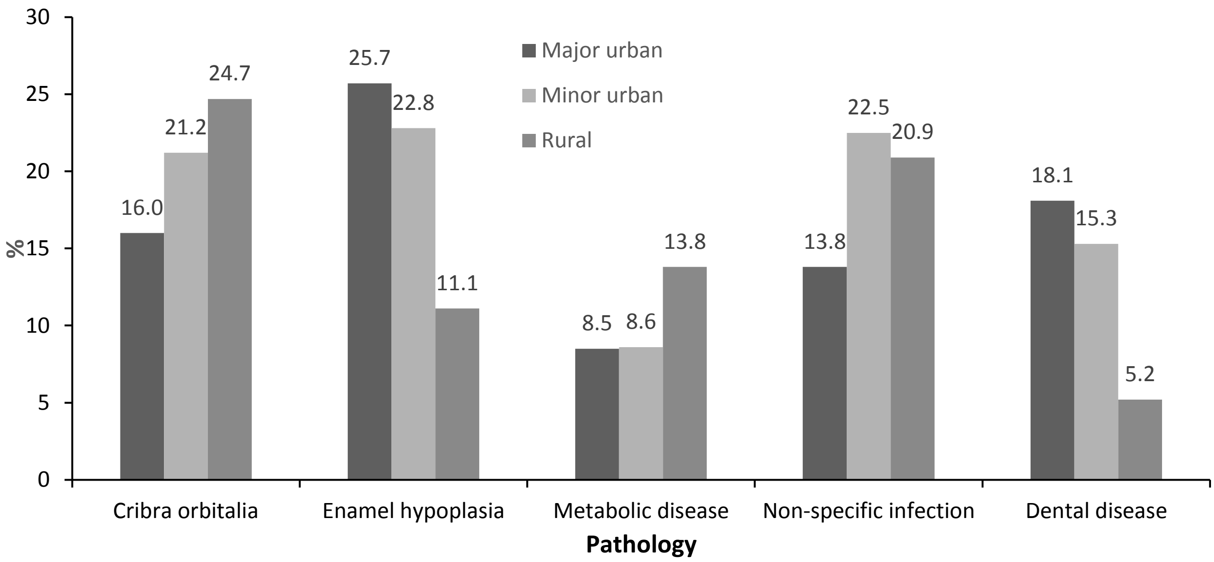


Figure 6.5. Distribution of pathology in burials without grave goods

6.5. DISCUSSION AND CONCLUSIONS: WERE ILL CHILDREN TREATED DIFFERENTLY IN DEATH?

Data on the burial archaeology of the primary study sample was extracted from cemetery plans and burial catalogues available in the site reports or the grey literature. For some collections, this information was simply not retrievable in detail, such as for the Gloucester burial grounds, Ancaster or Ashton, and some of the Baldock burials. Some burials, especially from rural contexts, were reported as disturbed, and any information on the initial deposit is lost. Therefore, it has to be emphasised that the results presented and discussed here are tentative at best. It also should be stressed that merely a broad overview of burial archaeology in relation to recorded pathologies was sought, as this study is primarily a palaeopathological investigation, rather than an evaluation of non-adult funerary archaeology. The funerary archaeology was only discussed when a skeleton was retrievable for analysis, therefore some burials that were described in the literature are not included here as they were not available for study at the time of analysis. Additionally, there are general caveats to the interpretation of burial and health in Roman Britain. Some aspects of late Romano-British burial practice may have been non-permanent, in addition to non-visible customs (Struck 2001). It is therefore sensible to consider that some variations in burial practice may have existed which cannot be seen using current archaeological and palaeopathological techniques. Pearce (2001b) also pointed out that, given the invisible burial rites prominently practised in the pre-Roman Iron Age, a proportion of the later Romano-British population may still have attributed these native invisible rites to their dead. This is certainly a point of interest, but we cannot estimate how valid this observation is for late Romano-British society. If an invisible rite was indeed persistently practised throughout Roman rule, it would have removed a portion of society from view and introduced inherent bias into the funerary record and therefore the palaeopathology of adults and children. It would have marked implications for our current understanding of Romano-British funerary ritual and the health of those buried, which cannot be gauged at the present time.

The majority of burials were aligned east-west, amounting to a total of 71.4%, and in urban (65.9% and 57.6%) as well as rural burial contexts (89.3%) individually. North-south alignment was the second most frequent grave position in major urban cemeteries (22.9%), however in both minor urban and rural burials, northeast-southwest was more common that strict north-south alignment, at rates of 30.4% and 8.4% respectively. It is interesting in itself that there were no statistically significant distributions between pathological lesions and burial alignment. We cannot assume that it was purely adopting Christianity or ‘Roman-ness’ that determined how a community laid out their cemeteries and the graves within it (Petts 2004; Pearce 2008). The local topography and man-made changes to the landscape such as roads or ditches would have influenced the space available for burial. Similarly, these factors would have dictated the organisation of burial space. It is therefore questionable how much the sociocultural identity of a community influenced the chosen burial alignment during the late Roman period (Pearce 2001b). The absence of a strong statistical relationship between alignment and ill-health is perhaps also a reflection of cultural norms in burial practices where standardised alignment was followed for most individuals, regardless of any differences in status or health in life. Additionally, we have to consider how visible some of the tested skeletal lesions were to the people of Roman Britain. Lesions such as cribra orbitalia would not have had a marked impact on the physical appearance of the children when they were alive, and may not have warranted a difference in burial alignment. However, Romano-British burial rites may have differed according to age and sex (Pearce 2013, 13-26). It is equally likely that sex-specific differences in health may have influenced how a grave was laid out, and the subtle differences that we have observed are a reflection of differential rites for boys and girls rather than the ‘well’ and ‘un-well’.

Standardised burial in simple rectangular earth-cut graves was most prominent in the major urban cemeteries, as only one perinate at Winchester deviated from the norm and was recovered from a pit. Interestingly, a range of unusual burial locations was reported for 17 (63.0%) of the 27 children under three years old from Roman Dunstable, including cesspits, wells and the ring ditch of the formal cemetery. Perhaps, these differences symbolise changes in belief systems or social identity at Dunstable (Watts 1989; 1991; 1998, 74; Petts 2003, 138). Disused wells were not only used for child burials, but also contained adult males and females (Matthews 1981, 11-13). However, burials in wet places are not uncommon in Britain during the Roman period, especially from the 4th century AD onwards (Esmonde Cleary 2000, 134-135). Perhaps the population at Dunstable was an outlier in terms of localised burial rites for men, women and children.

At Cannington, 14 children of all ages were buried at the periphery of the main cemetery, again this group was largely composed of infants and perinates. Burial of children, or mostly infants, in close proximity to the boundary features of a cemetery is not uncommon during the Roman period (Struck 1993; Pearce 2001a; Moore 2009). Additionally, this finding reinforces current theories on the liminal status of children younger than 12 months old (Moore 2009; Gowland et al. 2014; Millett and Gowland 2015). Intramural burial occurred at the rural sites of Catsgore and Bradley Hill in Somerset, indicating that this mode of burial may have been more prominent on rural sites. At Catsgore, all 19 individuals that were recorded have been recovered from within the settlement boundaries, either in buildings that served an agricultural or domestic function, or from under the eaves. Burial of infants and young children under the eaves of domestic structures was not out of the ordinary in late Roman Britain and Rome itself (Watts 1989; Philpott 1991, 97-101; Struck 1993; Scott 1999, 110, 115). These types of burial also increasingly feature in early Christian Anglo-Saxon sites, specifically in association with churches (Craig-Atkins 2014). Incorporating infant burials into domestic or agricultural buildings may have held a specific religious meaning for the grieving community, perhaps aiding the spirit or soul of the deceased in the afterlife, or allowing the deceased to remain in the community. Romano-British women may have buried their babies close-by in domestic contexts as a symbolic gesture associated with fertility of both the women in the community and the land (Scott 1991; 1999; Moore 2009; Gowland et al. 2014; Millett and Gowland 2015). At Bradley Hill, six of the 29 non-adults (20.7%) that have been available for study were buried in the formal site cemetery, whereas the remaining 23 individuals (79.3%) were buried within the settlement. It seems that burial of children in the site cemetery may have been the exception rather than the rule at this site. One of the children buried in the cemetery is an infant of under six months with possible scurvy, cribra orbitalia, and a clavicular fracture. Three of the children buried within the settlement exhibited skeletal indicators of infection and nutritional stress. The fact that individuals with compromised health were present in both burial groups suggests that illness in life was not the main differentiator that led the inhabitants of Bradley Hill to decide on intra- or extramural burial of deceased children. Perhaps during life, but at least in death, the children at Bradley Hill were treated equally. It may have mainly been the maintaining of close proximity of the living and the dead may have been a decisive factor in the burial location of young children at this site. The majority of these intramural burials contained the remains of infants and newborn babies, which may have similar symbolic connotations to the assemblage at Catsgore.

In the rural sample, there was a trend for higher rates of cribra orbitalia (38.3%; X^2=8.47, $p<0.01$, d.f.=1) and metabolic disease (16.4%; X^2=5.34, $p<0.05$, d.f.=1) to occur in children buried within formal cemeteries, as opposed to other locations. This is inevitably the result of the large Cannington assemblage constituting almost 70.0% of the rural burials, and cribra orbitalia and metabolic disease occurred at elevated rates in this cemetery. Additionally, the vast majority of children buried within the settlement boundaries are infants and newborns, and the likelihood of displaying skeletal lesions is lower in these age groups due to buffering against nutritional deficiencies via maternal nutrient stores and the infants' own reserves after birth (Brickley and Ives 2008, 45, 86).

Flexed or prone burials have been solely reported from major urban and minor urban cemeteries. This is an interesting observation, as prone burials in Roman Britain tend to occur in adult inhumations in rural contexts (Boylston et al. 2000). In the minor urban cemeteries, only two individuals were reported as buried prone, at Queenford Farm/Mill and Baldock of four and nine years of age respectively. These children displayed evidence for enamel hypoplasia, cribra orbitalia and non-specific infection which are not particularly unusual for children from minor urban cemeteries. Seven prone burials have been reported from the Bath Gate cemetery at Cirencester and the excavated cemetery areas across Roman Winchester. There are two individuals that stand out regarding their pathology: a 14-year old at Bath Gate with evidence for a respiratory infection, and a 12-year old (possibly a female) from Winchester with a large sinus on the right parietal bone, which may be a remnant of a soft tissue growth, fistula or even aneurysm which would have had varying health consequences of different magnitudes (Aufderheide and Rodriguez-Martin 1998, 78; Di Chiro and Doppman 1970; Mullan 1994; Perret and Nishioka 1966). Yet again, as a group, the children buried prone at Cirencester and Winchester did not differ markedly in their display of lesions from those buried supine as mainly cribra orbitalia, enamel hypoplasia and new bone formation were noted. It is difficult to assess the significance and symbolic importance of prone child burials with reference to palaeopathological markers. Perhaps the children discussed in the current study suffered from syndromes or diseases that marked them as different during their lifetime that cannot be discerned osteologically using current macroscopic techniques, or simply did not yield skeletal changes. It also remains unclear whether status differences were associated with prone burial: a 3-year old at Bath Gate was buried with jewellery, and the grave of the 10-year old buried prone at Chester Road, Winchester, contained pieces of pot. In contrast, the remaining seven prone burials were unfurnished. Other examples for prone non-adult burials are available in the literature and reiterate the complexity behind this mode of burial. However, prone burial is a common feature of Romano-British child burials where the osteology suggests a disability (Southwell-Wright 2014). At Poundbury Camp, Molleson (1989) reported four prone non-adult burials, one of which was of a deaf, possibly deaf-mute, child in the eastern periphery of the cemetery. Within the same area, another prone burial of an adolescent was reported, with a jet and glass bead necklace and no skeletal pathology (Farwell and Molleson 1993, 265). These examples show that prone burial can occur within the same site cemetery, yet produce very different connotations on the reasons why these children were placed into the grave differently than others. The sociocultural, status and health components that may have contributed to the decision-making of the grieving community to bury a child prone or supine may not be as straight-forward, and involve processes that are specific to the children and the site they were buried at (Struck 2001; Parker Pearson 2003, 54). Taylor (2008, 110) suggested that prone burial may be a way of ensuring the body is “overly secure” in burial, perhaps indicating that those burying the prone children wanted to enable a secure transition to the afterlife. Milella et al.’s (2015) appraisal of irregular burials in Britain and the Continent dating from the 1^{st}-5^{th} century AD also attests the complex nature of prone burials. Their interpretation is ever more challenging as they largely remain case studies in the literature rather than being discussed as a distinct burial group.

Grave goods were deposited at varying frequencies in the non-adult burials from urban and rural cemeteries. Coins were most frequently reported in child burials from major urban cemeteries. The coins may have been placed as Charon’s fee, which may reflect a greater affiliation with Roman belief systems, reminding us of the differences in uptake of ‘Roman-ness’ across Britain (Turner 2004). People living in the countryside, and at considerable distances away from major urban centres may have considered themselves less ‘Romanised’ whether by choice or analogy, than the town dwellers.

Personal adornments are amongst the most common grave goods in Roman Britain, particularly with children, and the presence of jewellery is frequently considered as a marker of high social status (Philpott 1993b; Pearce 1999a, 164). The fact that no items of personal adornment were present at all in the rural children is a pointer towards their lower status, or at least less wealth within the community (Struck 2001). No statistical relationship between the presence/absence of grave goods and skeletal lesions demonstrates that status and our current understanding of how it influenced the health of Romano-British children cannot simply be inferred by the company and nature of grave furnishings. Attitudes towards ill children may have varied, and perhaps the attribution of grave goods depended on the child’s family and their cultural and social identity, regardless of whether or not the child was affected by illness during life. Similar observations are made in ethnographic studies, where identities in life are not always a direct reflection of those attributed in the funerary ritual (Pearce 2001b). In Roman Britain, there are examples of disabled children buried with very unique items, such as the pipe-clay figurines found in the grave of a hydrocephalic child at Arrington in Cambridgeshire (Taylor et al. 1993). Similar figurines have also been found in the grave of a rachitic child in London (Conheeney 2000, 277-297). It has been suggested that these figurines were deposited to serve a protective function for these ill children (Fittock 2015). It is therefore more likely that very specific grave furnishings may be associated with ill-health in life, mainly those that serve a symbolic function to protect the child in the afterlife. However, the grave goods that were present for analysis in the current study may not have served such a purpose, and were therefore not associated with childhood health. After all, the deposition of grave goods is helpful in examining treatment in death, but ultimately reflects adult behaviour at the time of burial and may not necessarily relate to status, treatment and health that the child experienced during his or her lifetime (Jones 1993a; Gowland 2001).

The brief consideration of the grave goods between urban and rural cemeteries has shown that status, or at least access to items of personal adornments, may have been lower overall on rural sites. However, the rural children may not necessarily have been of lower status, it is merely their graves which are less wealthy than those of their urban peers (Struck 2001). We also should consider that the absence of jewellery in the graves of rural children may be reflecting a choice of the community who buried these children, rather than be a witness to the absence of jewellery itself within the community. Quensel-von-Kalben (2001) considered whether rural cemeteries were purposefully kept 'simpler' compared to urban burial grounds, the number of grave goods within these cemeteries would have therefore not been of importance. Integrating material evidence from the grave with a more holistic approach that appreciates the nuanced effects that status can have on health may prove more fruitful in future research (Jones 1993a; Goodman et al. 1995).

Overall, there seem to be no strong patterns between ill-health in Romano-British children and how there were buried. Otherness in life, defined by how (un)well these children were, did not influence their funerary archaeology, or at least not to an extent that left statistically evident patterns. Additionally, the results indicate that status was not necessarily an important factor in how children were buried (Jones 1993a). The observations made may simply be a reflection of the largely standardised nature of Romano-British inhumation burials, and plain simply availability of space and necessity of burial. Exceptions may have been far and few between, therefore not showing any differences in pathology between those buried in the standardised manner as opposed to those that are unusual. Perhaps 'otherness' marked by ill-health may have been imposed on children to a lesser extent by the community and family, therefore warranting largely uniform burial practices.

In some ways this is surprising as Lewis' (2010) study on metabolic disease and trauma in the children at Poundbury Camp showed marked differences in ill-health between the 'Roman' and pagan groups in the cemetery, based on differences in burial characteristics such as alignment and the presence/absence of grave goods. The findings of the current study do not negate that 'Roman' and pagan lifestyles had different effects on the health of children, but that these did not result in discernible patterns in the funerary archaeology. However, we also have to consider that Roman *Durnovaria* may have been different to the other sites included in the current primary study sample. It is arguably difficult to make meaningful associations between the alignment of graves and the health status of the children buried within them. It is almost impossible to separate choice from necessity regarding the direction in which a grave was cut into the ground. We also cannot assume that prone burials emulate a lack of care towards these children based on their physical health. Their paleopathology is not markedly different from others, neither are other aspects of their burials. Unusual funerary arrangement such as prone burial may not necessarily have been considered as careless by the burying community just because this is how we interpret it according to our own cultural values (Jones 1993a; Struck 2001). One of the few things we can however discern in this brief discussion of burial archaeology and palaeopathology, is a set of distinct burial rites for infants, particularly in rural environments. These favour burial locations outside of the main site cemetery, such as intramural interment, away from the dead community, and in closer proximity to the space of the living. Perhaps these rites communicate the liminal spirit of deceased infants and their separate status in life. There also seems to be a difference between urban and rural cemeteries regarding the type of grave goods that children were buried with, either reflecting a lower status of the rural population, a less 'Romanised' sense of identity in the rural population, or a different set of choices regarding the grave furnishings that children were awarded.

CHAPTER 7. DISCUSSION

7.1. LIMITATIONS OF THE STUDY

The nature of working with non-adult archaeological skeletal populations is that it is the study of non-survivors, which inherently biases the study population towards individuals who have not attained adulthood (Wood et al. 1992). The patterns of ill-health, stress and disease we observe in these children therefore have to be interpreted carefully. Under-representation of infants in urban burial grounds limits the interpretative value of differences in infant and perinatal mortality between sites (see section 5.3.2). The sample sizes are also influenced by preservation and representation which would have impacted on some of the rates of pathologies discussed, especially when substantial portions of the skeleton have to be present to make a valid probable diagnosis. Esmonde Cleary (2004) attested that the archaeologically most visible sites are those most 'Roman' in nature. Scarcity of skeletal remains from rural sites is a common problem in Romano-British bioarchaeology, and this study is no exception.

Another prominent limitation of this study is the potential presence of rural individuals in the urban cemeteries, thereby making both major and minor urban inhumations a mixed assemblage of town and country dwellers. However, we cannot currently estimate how noticeable this effect really was. All we know is that urban cemeteries would have included rural individuals either by migration into the towns, or due to living and working in villages and *villa* estates in the immediate hinterland. These individuals could have been members of either the elite or peasantry, which may have had different impacts on their health and wellbeing (Goodman 2007, 76-78; Laurence et al. 2011, 288; Griffin and Pitts 2012).

The combined sample comprised data from the published and grey literature, in addition to the data gathered from primary palaeopathological analysis. This sample allows for a broad overview of non-adult palaeopathology across Roman Britain. Some of the cemeteries were in use during the early Roman period (Winchester, Springhead, Owslebury), and others continued into the late Roman period (Poundbury, Butt Road, Chesterton, Bradley Hill, Catsgore, Watersmeet, Frocester). The osteological data therefore covers almost five centuries, allowing us to observe health patterns over a long time period.

Incorporating data from other sources has additional caveats. Some of the reports do not differentiate between perinates and infants, which may skew the ratios in the different newborn age categories. Not all skeletal reports rely on the same methods for ageing non-adults. Moorrees et al. (1963a,b) provide the most accurate method based on dental development, but a range of others are available (see section 4.2.2.2). Moorrees et al.

(1963a,b) have been used for ageing of the Poundbury assemblage (Lewis 2010; 2011; 2012), the non-adults from Roman London (WORD 2013), and in Clough and Boyle's (2010) report for Lankhills, Winchester. Moorrees et al. (1963a) are also cited in McKinley's (2011) report on the Springhead assemblage. The majority of the reports relied on epiphyseal closure, long bone lengths, and dental formation and eruption patterns using Ubelaker (1989) and Buikstra and Ubelaker (1994). The dental development and eruption chart provided by Ubelaker (1989) and Buikstra and Ubelaker (1994) is based on Schour and Massler's (1941) diagram with a study sample of unknown provenance. Some, or perhaps even all of the individuals included may have originated from Logan and Kronfeld's (1933) and Kronfeld's (1935) dental studies which comprised of children with developmental pathologies and other serious illnesses. Using this chart will therefore introduce inherent bias in the ageing of the non-adult cohort. Raising this issue underlines the importance of standardising ageing methods for non-adults to enable meaningful inter-site comparisons.

Even when following Moorrees et al. (1963a), the cut-off point of what was decided to be 17.0 years is not straight forward. Individuals were classed as non-adults when the roots of the third mandibular molar were complete but the apex remained open, and male and female age ranges had to be averaged, apart from adolescent individuals who could be sexed. This gives an average age of 16.9 years according to Smith (1991, 160). The mean age for complete mesial and distal roots of M3 is around 16.5 years for males and 17.0 years for females, the ranges for two standard deviations however stretch from 13.5 to 21.0 years, and older individuals may have been included in the adolescent age categories. During analysis of the primary dataset, in cases where the third molar remained in the mandible, radiographs were taken when possible to assess root formation. The Cannington and Trentholme Drive assemblages could not be radiographed due to curatorial restrictions, which will have impacted on the ageing of 14.6-17.0-year olds, especially for rural cemeteries as the Cannington assemblage is the largest one with 148 individuals. There is still no consensus in the palaeopathological literature as to who is classed as an adult as opposed to an adolescent (Falys and Lewis 2011). For example 'young adult' was used as a descriptive term for individuals from as young as 15 years, or alternatively from 19 years in some skeletal reports included in the combined study sample. These inconsistencies will have influenced the availability of 14.6-17.0-year olds from secondary sources. These issues highlight the need for standardisation of non-adult ageing to enable inter-site comparisons more readily and meaningfully.

Problems also arise when discussing palaeopathology from other sources, as methods for recording and analysis of pathological lesions in non-adult skeletons are continuously evolving. The literature on diagnosing vitamin C and D deficiencies, or anaemic conditions in non-adult skeletons has only recently expanded, and presented and developed more accurate methods. Brickley and Ives published new criteria for the identification of scurvy in young children in 2006, and it was not until 2012 that Lewis first proposed criteria necessary to identify non-adult thalassaemia and clearly differentiate it from vitamin D deficiency in the archaeological record. In 2008, Weston addressed the issues associated with labelling sub-periosteal new bone growth as non-specific infection without taking the overall health and disease state of the individual into account. Even more recent research by Zuckerman et al. (2014) proposed a new method for discerning cranial vault lesions due to scurvy as opposed to anaemia. Lewis (2011) also reiterated how to distinguish between tuberculosis and non-specific respiratory infections. The identification of widespread new bone formation as part of a diagnosis of either scurvy or tuberculosis also presents recurring issues (Santos and Roberts 2001; Brickley and Ives 2006). Non-adult palaeopathology is a new and evolving discipline within osteology. Although older skeletal reports have been excluded from analysis in the secondary study sample, even relatively recent skeletal reports written within the past 10 or 15 years would not have benefitted from some or all of these advances. The oldest report dates to 1997 for the excavations at Dorchester By-pass, Dorset (Jenkins 1997; Rogers 1997), and the most recent reports include the 2010 Oxford Archaeology report for Lankhills, Winchester by Boyle and Clough, and McKinley's 2011 skeletal report for the non-adults recovered by Wessex and Oxford Archaeology at Springhead in Kent during works for the Channel Tunnel Rail Link. These reports are very detailed and comprehensive, but the majority of skeletal reports date to the first half of the 2000s, and some instances of metabolic disease or infection may have been missed or erroneously labelled.

The palaeopathology of infants, especially below six months old, remains challenging. Widespread woven bone deposits, pitting and porosity are a sign of healthy regular bone growth that is deposited rapidly within these young children (Shopfner 1966; Kwon et al. 2002; Rana et al. 2009). Distinguishing bony changes as a result of vitamin C/D deficiency or infection is therefore inherently difficult. Infants below six months old have therefore been excluded from diagnoses for pathological new bone formation and endocranial lesions (Lewis 2004) (sections 4.2.4.2. and 4.2.4.3. for methods used). Brickley and Ives (2006) included young infants aged birth to six months to illustrate cranio-facial manifestations of scurvy, following Ortner et al.'s (1999; 2001) guidelines for distinguishing normal from abnormal porosity in this age group. These criteria were followed as closely as possible for making diagnoses for scurvy in perinatal and young infant remains in the primary study sample. Differentiating healthy from pathological new bone formation, pitting and porosity proved difficult, and it was therefore decided to exclude young infants from a further analysis of vitamin C deficiency (see section 5.3.4.5.3) (Fig. 7.1). It was also felt that a similar approach was necessary for discussing vitamin D deficiency in perinates. These measures were not taken to say that these deficiencies cannot occur due to compromised maternal health and therefore foetal stores, but as a means to controlling for over-diagnosing metabolic disease in perinates and young infants.

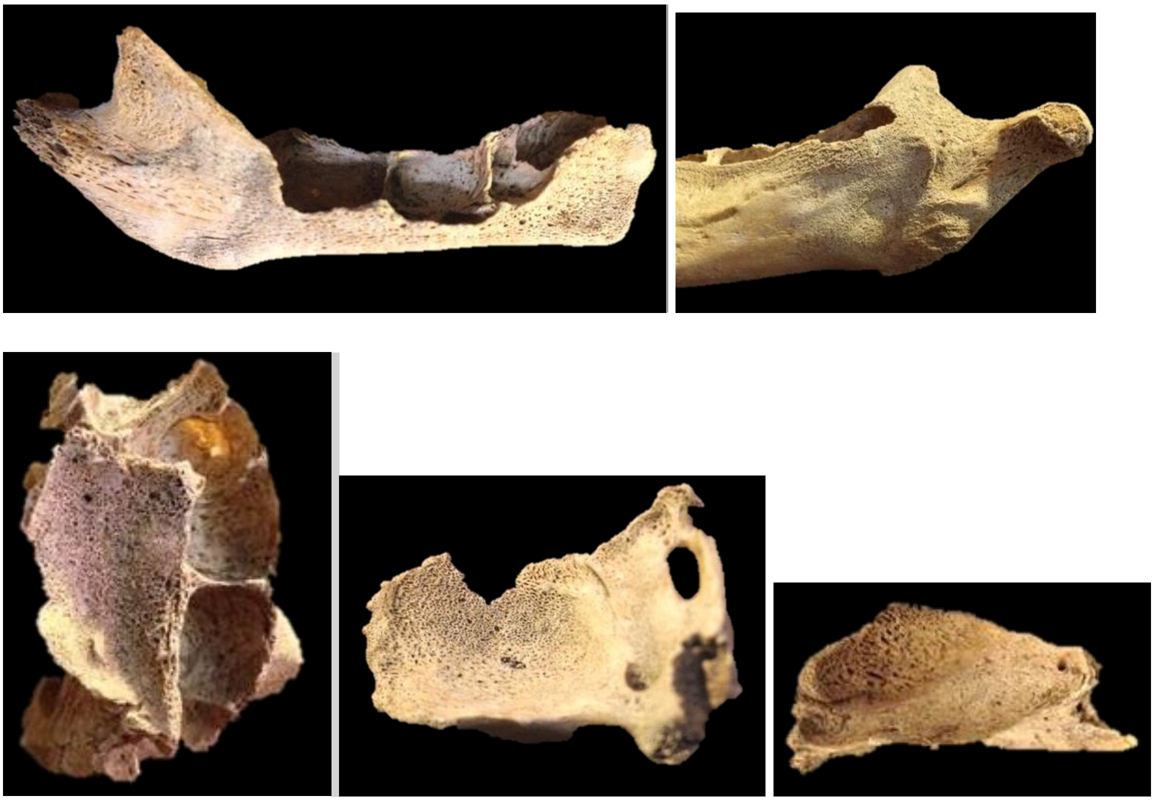


Figure 7.1. Examples of new bone formation, pitting and porosity possibly indicative of scurvy in neonates (with permission from Hampshire Arts and Museums Service, Somerset Heritage Centre and Winchester Museum Service)

7.2. PERINATAL AND INFANT MORTALITY – REALITY OR MIRAGE?

In the combined sample, the mortality pattern is one that was expected for a pre-industrial and pre-antibiotic society with mortality peaking around birth and infancy (Lewis 2002b,c; Lewis and Gowland 2007; Roberts and Manchester 2010, 37). Most striking is the greater number of preterm and perinatal infants represented in the rural sites (13.8% and 24.3%) compared to the major urban cemeteries (2.4% and 5.7%) which are significant differences at the 99% and 99.9% level. In archaeological remains, it is impossible to differentiate between preterm births and fullterm babies that are small-for-gestational-age, as ages are assigned based on diaphyseal lengths (Lewis and Gowland 2007). Nevertheless, the results seem to indicate that more rural babies were born prematurely, or were small-for gestational-age than was the case in towns. This would suggest compromised maternal health due to infection, heavy physical labour, environmental pressures and psychological stress during pregnancy, as well as close birth spacing and poverty (Dejin-Karlsson and Ostergren 2003; Federenko and Wadhwa 2004; Norton 2005; Steer 2005; Lewis 2007, 43). These peaks in mortality around the time of birth have also sparked ongoing debates regarding the widespread practice of infanticide in Roman Britain (Mays 1993, 2003; Gowland and Chamberlain 2002; Mays and Eyers 2011; Redfern and Gowland 2012, 120; Bonsall 2013a; Gowland et al. 2014; Millett and Gowland 2015).

However, it is not possible to simply interpret patterns of perinatal burials as equating to the number of deaths, as a difference in burial practices and recovery of the youngest members of Romano-British society are now recognised (Gowland et al. 2014). Some of the rural cemetery sites have a very high proportions of neonate burials, such as Owslebury in Hampshire (43.8% of total non-adult burials), Catsgore in Somerset (52.6%), and Frocester (81.4%) and Huntsman's Quarry (83.3%) in Gloucestershire. By contrast, several urban cemeteries had very low numbers of neonates, such as the London burial grounds (4%) and Butt Road in Colchester (2.8%). No neonates were recovered at Trentholme Drive in York, or the Gloucester cemeteries. Low representation of infants in the managed cemeteries also occurs outside of Roman Britain. For example in the north African city of Carthage, excavations at the Yasmina necropolis dating to the 3rd-5th century AD only uncovered one infant burial in a total of 60 non-adults (Norman 2002). Differential burial rites for those dying within the first year of life may have therefore been a contemporary ritual. Pliny in *Naturalis Historia* VII [15] describes children as lacking a soul until the age of teething at around six months, which may account for their different treatment in death (Philpott 1991, 101). Funerary practice may have dictated the interment of babies within the settlement boundaries, in clusters in a dedicated area of the cemetery, or at a separate site altogether, ultimately impacting on the urban and rural rates of infant mortality observed in this study (Philpott 1991, 101; Scott 1991, 120; Pearce 1999a,b; Esmonde Cleary 2000; Wileman 2005, 80-81, 99; Gowland et al. 2014).

Analysis of the rest of the infant group shows similar complications. The large percentage of perinates recovered from Frocester is even more remarkable for the total absence of older infants, suggesting this may be a designated perinatal burial site. Proportions of older infants are significantly higher in the minor urban sites at 32.9% (X^2=30.58; p<0.001, d.f.=2), compared to the rural (24.3%) and major urban sites (19.2%). Some scholars have suggested the existence of 'infant corners' that may remain unexcavated in major urban sites where pre-existing buildings prevent large scale excavation, and these have yet to be identified in the archaeological record (Philpott 1991, 101; Pearce 1999a, 154; Esmonde Cleary 2000, 135; Moore 2009). Although these areas of clustered infant burials have not been validated in major urban settlements as of yet, they may have still influenced the urban-rural differences observed.

Analysis of the primary data allows for these issues to be explored in greater detail without the inherent problems of different methods and recoding strategies. The primary data reflected that of the combined, and over a third of all children died before reaching six months of age. However, the prevalence of perinatal remains in the rural sample seen in the combined data is not evident here, and rates of perinatal deaths are similar in urban and rural cemeteries. Examination of neonatal and post-neonatal mortality in the 187 perinates recorded showed that the majority (over 95%) were aged 38-40 weeks, or neonates. This is a common observation when discussing perinatal mortality using regression statistics for ageing (Gowland and Chamberlain 2002; Lewis and Gowland 2007; Bonsall 2013a). Neonatal deaths are caused by endogenous factors and reflect problems inherent at birth such as congenital defects or birth trauma, and are most commonly seen in rural groups today (Frenzen and Hogan 1982). Scott and Duncan (1999b) attested that exogenous environmental factors, such as infection, nutrition, poisoning and accidents are decisive in post-neonatal mortality, and can therefore be used to remark on the different stresses experienced by mothers and babies in urban and rural environments in Roman Britain. Previous studies have shown that urbanisation and increased industrialisation in past populations triggered elevated post-neonatal mortality (Vögele 1994; Lewis and Gowland 2007; Humphrey et al. 2012). The urban environment, with all its drawbacks for health frequently elaborated on in the literature on life in the Roman Empire, would have presented greater risk factors for post-neonatal mortality, such as infection, overcrowding and pollution (Rawson 2003a, 121; Roberts and Cox 2003, 123-130). The paucity of post-neonatal deaths in the primary study sample may indicate that such dangers did not actually exist in the past. However this seems unlikely, and this pattern is probably due to the under-representation and differential burial rites of infants already discussed. Unfortunately we have to accept that distinct burial rites for those dying within the first year of life are highly likely, therefore presenting a major caveat for the interpretation of infant mortality patterns and the validity of inferences made about endogenous and exogenous factors acting on mothers and their babies.

7.3. GROWTH

Growth is regarded as an indicator for overall health of a population and its ability to adapt to a changing environment (Goodman and Martin 2002, 20-21). Poverty is seen as the main causative agent behind slower or stunted growth between different populations within the same social context (Tanner and Eveleth 1976, 161; Saunders and Hoppa 1993; Bogin 1999, 304-305; Cardoso 2007). However the interaction of many intrinsic and extrinsic factors ultimately affect growth and final height attainment of an individual, including catch-up growth, cultural buffering and social inequality (Redfern and Gowland 2012, 118; Vercellotti et al. 2014). Comparison of femoral diaphyseal lengths between the three site types revealed no significant differences, although the rural children were generally shorter than their urban peers. As one group, the Romano-British children were on average smaller than the modern healthy children measured by Maresh (1955), although the results are not statistically significant. This discrepancy increased after the age of 13 years. It may be that Romano-British children went through puberty at around the same time as modern children do, commencing at 10-12 years (Eveleth and Tanner 1990, 27; Bogin 1999, 87, 91). In Rome itself, legal, written and iconographic sources refer to puberty as the stage when childhood officially ends, at 12 years for girls, and 14 years for boys (Harlow and Laurence 2002, 56-57; Rawson 2003a, 142; Gowland and Redfern 2010). Perhaps the slower growth in the Romano-British children compared to the modern sample from around 13 years is a product of changes in activity patterns which affect height attainment and entrance into puberty. If greater energy was expended on manual labour for example, development may have slowed down (Tanner 1987) (see sections 7.12 and 7.14). The inability to sex the Romano-British cohort accurately inherently limits the scope of interpretation of the growth curves regarding the pubescent growth spurt, even though Maresh's (1955) data has been modified to contain mean measurements for boys and girls (Saunders and Hoppa 1993; Visser 1998). Additionally, some of the variation may be due to genetic or environmental factors. To illustrate, Roberts and Cox (2003, 142) stated that the mean adult stature in Roman Britain was 169 cm for males and 159 cm for females. The 2009 Health Survey in England reported mean adult height at 175 cm for men and 161 cm for women (Health and Social Care Information Centre 2010). With greater mean adult height in modern British populations as opposed to Romano-British adults, it is not surprising that children in the Roman period exhibited shorter mean diaphyseal lengths than Maresh's (1955) study population.

7.3.1. Growth in Roman Britain and post-medieval London

Given previous comments about the health of Romano-British children being as bad as, if not worse than in post-medieval England (Lewis 2011), it was of interest to evaluate growth between both time periods. Femoral growth profiles were compared with post-medieval non-adults from Christ Church, Spitalfields in east London. The cemetery dates to the later 18th and first half of the 19th century, with parish records stating a middle to upper class background of the deceased adults (Lewis 2002b, 32). A scatterplot with the regression line for the Spitalfields and Romano-British non-adults is shown in Figure 7.2 below. The individual femoral length measurements for the non-adults from Roman Britain and Christ Church, Spitalfields are tabulated in A6.12 (in Appendix VI).

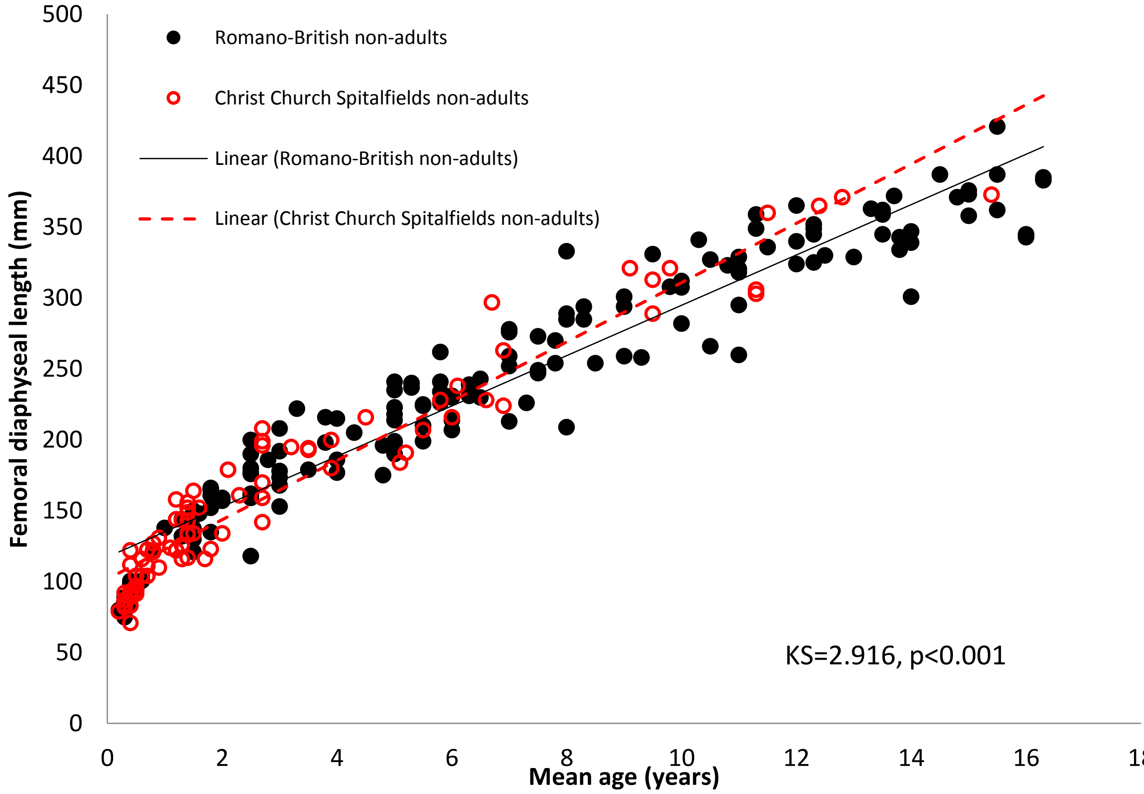


Figure 7.2. Femoral length in Romano-British and Post-medieval non-adults

The distribution of femoral length measurements differs significantly between the two samples (KS=2.916, $p<0.001$), and the Romano-British cohort is significantly shorter than the post-medieval non-adults overall. The Romano-British non-adults have longer femoral diaphyseal measurements during infancy and early childhood until about five years of age. This change in relationship between growth patterns of both populations is intriguing, as growth under the age of five years may be shaped by nutrition-infection interactions secondary to breastfeeding and weaning habits (Goodman and Armelagos 1989; King and Ulijaszek 1999, 177). It has been suggested that infants of wealthy parents in the Spitalfields area may have been sent to the countryside to be breastfed by wet nurses (Fildes 1986, 152-153; Lewis 2002b,c), which would affect the socioeconomic background of the children under five years included here, as only those whose parents could not afford a wet nurse. Isotopic analysis of some of the Spitalfields non-adults indicates that supplementary foods were introduced before the end of the first year, and breastfeeding would have ceased by two years old. There may have been more than one weaning strategy that was adhered to, and not all infants were breastfed as fads such as feeding infants by hand became increasingly fashionable (Nitsch et al. 2011). Lewis (2002b, 54-55) suggested that chronic under- or malnutrition and lack of exposure to sunlight would have been prevalent in the younger children. The latter would have been the result of the urban living environment, whereas insufficient nutrients in the diet would have been the result of the specific supplementary foods given, such as pap (flour/breadcrumbs cooked in water or milk) (Fildes 1986, 213; Lewis 2002b, 55). The difference in growth between Romano-British under 5-year olds and those from Spitalfields may be a reflection of overall more adequate weaning and feeding practices in the Roman period compared to Industrial London, with a lower exposure to infectious agents via food and the environment (King and Ulijaszek 1999, 168-170). This demonstrates an overall better-adapted weaning strategy. Better nourishment in the Roman children under five years old would have helped them to be more resilient to infection, parasites and diarrhoea, and therefore enabled them to grow and flourish better than those in post-medieval London (Kuzawa 1998; Brown 2003; Dewey and Mayers 2011). Alternatively, children in Roman Britain may have experienced under- or malnutrition to the same or similar extent as post-medieval children, but stress and pathogen exposure were overall less drastic in Roman Britain, which enabled these young children to grow better.

From around five years old, Romano-British children fall significantly below their Spitalfields peers for femoral length. Post-medieval industrial London is viewed as the quintessentially 'bad' living environment: poor sanitation, crowding, air pollution; its inhabitants are having to perform strenuous physical labour without adequate nutrition and rest (Lewis 2002b, 5). The shorter stature of Romano-British children over five years compared to the Spitalfields sample does not dictate a higher risk of morbidity, but rather pinpoints different diseases and stresses acting on these populations, prompting differences in stature as a bi-product of differential morbidity (Saunders and Hoppa 1993).

The observation of Romano-British children exhibiting stunted growth compared to the post-medieval cohort may imply a different or even greater environmental burden and malnutrition-infection interactions in Roman Britain. Children in Roman Britain may have experienced a shift in nutrition from around five years old. Scrimshaw et al. (1968, 55-56) and Dewey and Mayers (2011) stated that the impact of infection on growth can be somewhat mediated, but not prevented, by a good nutritional status. Good nourishment will either limit stunting, or enable catch-up growth once the infectious episode has subsided (Bogin 1999, 81; Dewey and Mayers 2011). It is therefore suggested that Romano-British children faced long-term under- or malnourishment from five years old, which elevated risks for infection and reduced their ability to increase growth velocity for catch-up growth (Guerrant et al. 1992; Bogin 1999, 81; King and Ulijaszek 1999, 174-176; Dewey and Mayers 2011). Alternatively, they may have suffered compromised health earlier, and it is not until around five years when this comes into effect resulting in growth retardation. Children may reach a mid-growth spurt between the ages of 6-8 years (Bogin 1999, 78, 405), and deviations in growth between both samples may have arisen due to increased growth velocity on the Spitalfields children, whereas the Romano-British cohort may not have undergone a growth spurt at the same increased velocity. While the mid-growth spurt has been recognised as a small increase in growth velocity during childhood, its onset and average velocity differs between populations and the sexes (Molinari et al. 1980; Tanner and Cameron 1980; Berkey et al. 1983; Tanner 1988; Butler et al. 1990; Remer and Manz 2001). However, even when taking the mid-growth spurt into consideration, it still does not account for growth retardation from five years old. However, it has to be borne in mind that the study population is not contemporary with post-medieval London, and compares a geographically dispersed sample against a spatially fixed population. For both populations, diaphyseal lengths are derived from individuals that have been buried over a wide time span which is a general limitation of cross-sectional data.

There are also very sample specific issues involved. Children during the post-medieval period may have migrated to the towns from around 7-10 years old to find employment as apprentices (Sharpe 1991; Lewis 2002c). Arguably, this would introduce rural individuals into the Spitalfields cemetery who were unable to return home before they died (Pelling 1988), although the Spitalfields non-adults are generally considered as those of wealthy Londoners (Lewis 2002c). There may be uneven sex ratios in both the Spitalfields and Romano-British samples, which interfere with the timing of peak height velocity during the adolescent years, as comparing a sample with male bias with a sample with female bias will inherently introduce deviations in growth rates and mean femoral lengths from around 12 years old (Largo et al. 1978; Eveleth and Tanner 1990, 27-28; Bogin 1999, 88). Under- or malnourishment in the Romano-British group may have led to growth retardation from five years and persisted through puberty. Genetic predisposition or undernutrition may have also contributed to the disparities in femoral diaphyseal lengths, and the widening gap between Spitalfields and Romano-British adolescents. Post-medieval adults have been shown to have been taller than Romano British populations (Roberts and Cox 2003, 103, 142, 308). Growth retardation in the Romano-British non-adults may therefore be the result of smaller attained adult height. Alternatively, the Romano-British cohort represents a genetically more diverse group, compared to the post-medieval non-adult sample which is smaller and would have been primarily from London.

There are also five outliers at the bottom range of femoral diaphyseal lengths in the Romano-British sample, at the ages of eight, 11, 14 and 16 years. The 11-year old displayed caries, and the 14-year old was recorded with enamel hypoplasia and active grade 5 cribra orbitalia. No severe pathologies or congenital conditions that promote shorter stature were observed. Interestingly, all five stemmed from major and minor urban cemeteries. Although these outliers may have somewhat influenced the regression line for average femoral length increase in the Romano-British cohort, they only account for 5.2% of the total of 97 diaphyseal measurements included for children over five years, and their impact may be negligible. Being aware of the caveats, it is still intriguing that Romano-British children were overall less well adapted to their living environments, and on the whole ‘unhealthier’ or less well-nourished than children in post-medieval London (King and Ulijaszek 1999, 161; Saunders 2008, 134). Rather than implying worse living conditions in rural and urban Roman Britain than Industrial London, this result may point to changing lifestyles experienced in Roman Britain. Overall health may have declined throughout the Roman occupation of Britain, as its inhabitants struggled with urban living and agricultural modernisation, resulting in widespread under- or malnutrition.

7.3.2. Urban versus rural growth

Comparison of femoral diaphyseal lengths between the three site types revealed no significant differences, although the rural children are collectively shorter than their urban peers. This result is surprising, as it was expected that children in the countryside would have benefitted from better health and therefore taller stature, whilst their urban peers were affected by the disease- and stress-promoting effects of urbanisation. This result supports that urban environments did not represent exponentially worse conditions for childhood health in the Roman period, whilst also implying that rural settlements did not provide a significantly better living environment. Bonsall (2013b, 228-230) made similar observations when comparing non-adult growth profiles from Ancaster and Winchester, attesting similarities in mean stature and therefore inferring a comparable health and nutritional status. There is no divergence in the growth profiles between the rural, minor urban and major urban individuals from the age of 12 onwards, which does not suggest differences in sex distribution between the cemeteries based on the timing of the adolescent growth spurt (Eveleth and Tanner 1990, 27-28; Bogin 1999, 88). Given the observations on mortality in Romano-British children, it may be inferred that this is a generally stressed population, where growth faltering occurred at a similar rate regardless of living environment.

7.3.3. Pathology and growth

Plotting femoral diaphyseal lengths of individuals with and without enamel hypoplasia has revealed statistically significant differences in growth between both cohorts, albeit at the 99.5% level (KS=1.745, p=0.005). Until 10 years of age, children with enamel hypoplasia displayed significantly longer femoral lengths, the relationship was then reversed. Those with enamel hypoplasia represent a group strong enough to undergo a health insult in early childhood and recover from it, whilst upholding higher growth velocity than those without enamel defects via catch-up growth (Eveleth and Tanner 1990, 191-192; Wood et al. 1992; Goodman and Martin 2002, 27; Paine and Boldsen 2002, 174). Growth retardation only sets in once the children with enamel hypoplasia should be reaching peak height velocity during the adolescent growth spurt (Largo et al. 1978). This may be a result of the "Barker Hypothesis" which attests that illnesses in later life often have a fetal or early childhood origin (Armelagos et al. 2009), and in this instance may have impacted on growth. Alternatively, these individuals may represent a chronically stressed cohort that cannot attain the same growth rate as those without enamel hypoplasia (Eveleth and Tanner 1990, 192). Although these individuals would have gone through periods of catch-up growth and extension of the adolescent growth spurt, they were overall lagging behind those without early childhood episodes of stress. As these children died prior to having attained full adult height, the delay in growth and prolonged acceleration of adolescent growth led to shorter femoral lengths compared to children without enamel hypoplasia (Eveleth and Tanner 1990, 191-192; Bogin 1999, 90-92). This reasoning, discussing growth rates between children with and without hypoplastic lesions, is however limited by the nature of the cross-sectional data, which only measures the final diaphyseal length attained by non-survivors at the point of death. We also cannot infer whether these children reached peak height velocity before death, which applies to both the sample with enamel lesions and those without. Also, as the non-adults have not been sexed, we cannot be sure whether some of these differences in growth also relate to different sex compositions of the two cohorts. Lastly, we cannot ascertain what these children died of and have to consider acute conditions that would not impact on growth or maturation (Lovejoy et al. 1990; Saunders and Hoppa 1993; Lewis et al. 2015).

Growth in children with new bone formation compared to those without does not differ statistically. The absence of a significant difference between both samples shows that new bone formation does not have an impact on non-adult growth in Roman Britain (KS=1.045, p=0.225). Catch up growth in individuals with new bone formation would have enabled these children to attain the same height as their peers without inflammation or infection, provided they maintained a good nutritional status and the infection was short term (Eveleth and Tanner 1990, 192; Bogin 1999, 81; Dewey and Mayers 2011). Nearly 85% of the individuals with sub-periosteal new bone formation showed no evidence for healing. The inflammation had therefore occurred only shortly before death, possibly within a few weeks, potentially too soon to affect growth (Weston 2008). Selye (1976, 129) described inflammation as a local reaction to injury, rather than a systemic response. Inflammation is not always related to infection, and the possibility of lesion formation as a response to relatively minor trauma also has to be considered. Sudden or chronic insult to bone can initiate a periosteal reaction that is not part of a systemic infection or localised bacterial focus (Ragsdale et al. 1981; Ortner 2003, 208). Traumatic periosteal reactions would therefore not have an impact on growth to the same extent as undernourishment or widespread infection for example.

Lastly, growth in the individuals with cribra orbitalia compared to those without orbital lesions also does not differ significantly (KS=1.248, p=0.89). This stress marker therefore has little impact on overall growth in Romano-British non-adult populations. We have to consider the possibility of visible and invisible stress associated with malnutrition and infection (McIlvaine 2013), which would lead to similar levels of stress in individuals with and without cribra orbitalia. This result was not entirely unexpected as the exact aetiology behind lesions on the orbital roof remains disputed, as does the severity of the underlying genetic or acquired anaemia (Walker et al. 2009; Oxenham and Cavill 2010; McIlvaine 2013). A similar observation was made for femoral growth in children with and without vitamin C/D deficiencies (KS=1.238, p=0.093). Shorter diaphyseal lengths throughout in the cohort with rickets/scurvy were observed, as an adequate nutritional status is paramount in ensuring healthy growth (Bogin 1999, 240; King and Ulijaszek 1999, 161-162). However, small sample size may have triggered a non-significant result. Only 10 individuals with metabolic disease had intact femora for measurement, compared with 142 from individuals without.

Nevertheless, the absence of a statistically significant difference in femoral lengths is surprising. It was anticipated that non-adults diagnosed with rickets/scurvy experienced growth retardation based on previous findings at Christ Church, Spitalfields (Lewis 2002b, 49-50). However, Pinhasi et al.'s (2006) study of long bone growth in children aged 0-3 years old from post-medieval London from both the Christ Church Spitalfields and Broadgate cemeteries, showed that rickets in isolation did not account for stunted growth. Socioeconomic status was rather the decisive factor that dictated differences in growth, although we also have to consider catch-up growth in those with rickets, and the fact that rachitic individuals may not have experienced significant length reductions or bowing of the long bones. Based on these findings, the Romano-British children with rickets/scurvy may not have experienced growth retardation after all.

7.4. PATTERNS IN DENTAL DISEASE: DIET AND CHILDCARE

The aim of the investigation of dental disease patterns across urban and rural settlements in Roman Britain was to explore overall oral health and infection, informing on the social and spatial diversity of foods consumed. This in turn enables us to consider childhood feeding practices and cultural attitudes towards eating and drinking in childhood, which apart from the weaning diet we know surprisingly little about.

Both crude and true prevalence rates indicate a higher incidence of caries in major urban as opposed to rural non-adults (CPR 18.5%/5.1% and TPR 1.8%/0.4%). Additionally the true prevalence rate of deciduous caries is significantly higher in major urban children at 3.0%. The significantly lower rate of deciduous caries in non-adults from rural settlements suggests differences in early childhood diet and food processing between urban and rural communities. A true prevalence rate of 0.2% was reported for this group, and this rate is similar to the one reported from Roman Dorset at TPR 0.3% (Redfern et al. 2012). Sweetened and carbohydrate-rich foods of softer consistency may have been more readily available in urbanised areas, whereas foods with a high monosaccharide content may have been eaten less frequently in rural areas. A diet high in grit, with hard and abrasive fibrous foods or contaminants will also prevent caries attacks, although tooth wear was not recorded in the current study (Duray 1992; Moynihan 2000).

In the primary study sample, a significantly higher rate of carious lesions was recorded in the posterior dentition with a TPR of 2.3% (X^2=42.65, p<0.001, d.f.=1). This result was expected as carious lesions occur more frequently in molars due to greater surface area, and pits and fissures which plaque can adhere to more easily (Hillson 1996, 272). There was also a trend for more carious lesions to affect the deciduous (TPR 1.8%) as opposed to the permanent dentition (TPR 1.1%; X^2=4.10, p<0.05, d.f.=1). Although this result is not significant at 99.9% confidence, it is still worthy of discussion. This trend was anticipated as the deciduous dentition is more susceptible to caries due to differences in enamel hardness (Hunter et al. 2000; Halcrow et al. 2013). Transitional and weaning foods would have been soft and carbohydrate-rich, such as porridge or bread soaked in wine, milk or honey (Temkin 1991, 117; Garnsey 1999, 107), promoting deciduous tooth decay.

National data for adult dental disease in the Roman period is provided by Roberts and Cox (2003, 131-137). The true prevalence rate for caries in adult males and females was 7.5%. Whittaker et al. (1981) reported a very high overall true prevalence rate of 15.8% for caries in a sample of 517 skulls from adults and non-adults at Poundbury Camp. These rates may give reference points for infections in the oral cavity in Romano-British non-adults, as dental disease is age progressive and is expected to be higher in adults. The results for crude and true prevalence rates of carious lesions reported in previous studies for Romano-British non-adults are tabulated in Table 7.1. The overall crude prevalence rate for caries reported in the primary study sample was 11.3% for all three settlement types. Interestingly, the crude prevalence rate for caries in the major urban children in the primary study sample (CPR 14.8%) is substantially higher than the crude prevalence of non-adult caries at Poundbury Camp (CPR 3.6%, Lewis pers, comm.). The latter is in fact similar to the crude prevalence of caries in the rural children at CPR 3.8%. This is a surprising finding, as caries rates at Poundbury Camp were expected to be high, in keeping with other Romano-British major urban settlements. However, as discussed in section 7.14, this may be another indication of the peculiar nature of the population buried in the Poundbury Camp cemetery. The majority of the population at Roman Dorchester and in its surrounding areas may have been of lower status compared to other major urban towns in Roman Britain. This would be reflected in the foods consumed, diet may have been ‘simpler’ and similar to those consumed on rural sites. True prevalence rates of caries demonstrate that lesions occurred statistically more often in major urban non-adults (TPR 1.8%, n=49) compared to those from rural sites (TPR 0.4%, n=4; X^2=12.06, p<0.001, d.f.=1). The rate reported for the major urban sample is similar to the rate of carious lesions at Lankhills, Winchester at TPR 1.7% (Clough and Boyle 2010). True prevalence rates for deciduous caries were also higher in major urban sites at TPR 3.0%. Moore and Corbett (1973) reported a true prevalence rate of 4.2% for deciduous caries in children from major urban and military settlements in Roman Britain. It is likely that the inclusion of individuals from military sites or surrounding *vici* may have elevated caries rates due to differences in food processing and consumption (Cool 2006). Dietary differences between military and civilian settlements have been discussed previously in the literature, demonstrating that the military diet may have been more 'Romanised' (King 1984, 1999; Alcock 2003; Cool 2006; Redfern et al. 2010; Britton and Huntley 2011). Those living in the *vicus* may have eaten a similar diet which may have impacted on the rate of dental infection and decay in the children. However, Moore and Corbett's (1973) sample is very small with only eight non-adults providing 51 deciduous teeth. O'Sullivan et al. (1993) also provide comparative data and reported a true prevalence rate of 16.0% for caries in deciduous molars specifically. Examining caries in the deciduous molars in the current study has also shown significantly higher rates in the major urban cohort at TPR 4.8%, compared to none reported in the rural sample (X^2=12.24, p<0.001, d.f.=1). Interestingly, the rate reported in the present study is considerably lower than O'Sullivan et al.'s (1993) observed rate. The specific settlement contexts that the data were derived from for O'Sullivan et al.'s (1993) study are not provided, apart from the period (1st-5th century AD) and regions (Dorchester, Chester, Berkshire, Gloucestershire, Stratford). We cannot rule out that some of these include military contexts, which would have altered caries frequencies, and may have been selective regarding the completeness of dentitions for observation.

Table 7.1. Caries rates previously reported in Romano-British non-adults

Study	Context (century AD)	CPR	TPR	Comments
Moore and Corbett (1973)	Various major urban/military (1st-5th)		4.2%	Deciduous teeth
O'Sullivan et al. (1993)	Various (1st-5th)		16.0%	Deciduous molars
Clough and Boyle (2010)	Lankhills, Winchester (4th)		1.7%	Deciduous and permanent teeth
Redfern et al. (2012)	Dorset various, (1st-5th)		0.3%/1.5%	Deciduous/permanent teeth
Lewis (pers. comm.)	Poundbury Camp (3rd-5th)	3.6%		Deciduous and permanent teeth

We may be able to contextualise dental decay by comparing caries rates from Italy with those reported in the children from major urban Romano-British settlements (see Prowse 2011 for an appraisal of dental health through the Roman life course). Prowse et al. (2008) reported a true prevalence rate of 3.8% for carious lesions in the teeth of 1-12-year olds from the necropolis at Isola Sacra at Portus near Ostia. Although the deciduous caries rate in major urban settlements (TPR 3.0%) was significantly higher than elsewhere in Roman Britain, the rate is still below those of children in major urban settlements near Rome itself. This may indicate that major urban centres in Roman Britain shared some dietary habits with those at the centre of the Empire. In Roman Britain overall however, childhood diet either followed a slightly different pattern, or Romano-British children exhibited genetic factors and greater fluoride exposure to prevent them from developing similarly high caries rates (Sreebny 1983; Woodward and Walker 1994).

Today, caries in children under six years old is associated with certain feeding behaviours (Hallet and O'Rourke 2003; Azevedo et al. 2005; Gussy et al. 2006). In the major urban cohort, caries was elevated in children under 6.5 years old, and this is also the only group with caries in the anterior deciduous dentition. Anterior deciduous caries was solely reported in major urban and minor urban children albeit at low rates of TPR 0.5% and TPR 0.8% respectively. When the different pathogenesis of severe early childhood caries in the toddler from Ancaster is accounted for and the five affected anterior teeth are removed, the minor urban true prevalence rate equals 0. Caries in the anterior dentition was therefore exclusively found in major urban non-adults, affecting the deciduous canine in the maxillary dentition of a 5-year old from Kingsholm, Gloucester, and the mandibular deciduous canine of a 9-year old from the northern cemetery at Winchester. Perhaps Romano-British mothers or caregivers in those urban environments exhibited certain feeding behaviours, such as on-demand-feeding or letting the infant continuously sip on sweetened liquids, such as those suggested by Soranus (II46[115]) (Temkin 1991, 117). This in turn may have led to carious lesion development on the anterior teeth. Bottle-feeding itself during the Roman period is disputed. Some archaeological and written evidence for feeding vessels with a spout exists, which makes occasional bottle-feeding, or bottle-feeding during transitional feeding plausible (Fildes 1981; 1986, 35; Eckardt 1999). Soranus (II 49[118]) suggested rubbing honey on the gums to soothe teething infants, and "poultices of the finest meal, or fenugreek or linseed and fomentations with sea sponges, especially for the gums" (Temkin 1991, 119-120). Orally administering soothers and pain relief may also have had a pacifying function. Although there is no evidence for the use of pacifiers in Roman Britain, or Rome for that matter. Given the use of honey and poultices were recommended during teething, it is not unreasonable to suggest that infants and young children may have been given sweetened cloths to chew or suck on, similar to the 'sugar rag' first documented on Continental Europe in the 16th century (Marter and Agruss 2007). However, the primary form of evidence for pacification is severe early childhood caries affecting the anterior maxillary deciduous dentition which, to date, has only been reported once in Roman Britain (Bonsall et al. 2015).

The youngest individual with caries is a 2.5-year old from Butt Road, Colchester with occlusal caries on the maxillary second molar who marks the youngest individual with caries reported from Roman Britain to date. There is an increase in caries rates from 1.1-2.5 year olds to the 2.6-6.5-year olds from TPR 0.1% to 1.8%. However, nine of the 16 teeth affected by caries in the minor urban 2.6-6.5-year old cohort stem from the 3-year old at Ancaster with severe early childhood caries, and have been omitted in Table 7.2 for age-based trends. Even without this individual, there is still an increase in carious lesion frequency by 1.1% between 1.1-2.5 and 2.6-6.5-year olds.

Table 7.2. Revised true prevalence rates of carious lesions by age

	Major urban			**Minor urban**			**Rural**			**Total**		
Age (yrs)	*n*	*%*	*N*	*n*	*%*	*N*	*n*	*%*	*N*	***n***	***%***	***N***
1.1-2.5	1	0.3	394	0	0	571	0	0	193	**1**	**0.1**	**1158**
2.6-6.5	12	2.2	555	7	0.9	773	0	0	254	**19**	**1.2**	**1582**
6.6-10.5	20	3.7	539	4	1.0	393	0	0	112	**24**	**2.3**	**1044**
10.6-14.5	11	1.3	883	11	2.1	520	1	0.3	315	**23**	**1.3**	**1718**
14.5-17.0	5	2.4	213	6	3.1	195	3	0.9	351	**14**	**1.8**	**759**

Initial colonisation of the oral cavity with carious bacteria would have commenced from around one year due to the window of 13-16 months between invasion with *S. mutans* and the onset of carious lesions (Kawashita et al. 2011). However, the administration of cariogenic foods and feeding habits may have been in place earlier from when infants start to sit up at around six months through to developing better chewing and tasting mechanisms, and self-feeding from around 12 months (Sheridan 1975, 29; Sellen 2001; 2007; Carruth and Skinner 2002; Delaney and Arvedson 2008). *S. mutans* are mainly transmitted from the primary care giver to the infant as soon as tooth surfaces have erupted (Gussy et al. 2006). Early childcare in Rome was not only undertaken by the mother, but also often a *nutrix* or *paedagogus* among richer families (McWilliam 2013, 277). Children could have also been cared for by neighbours, friends or relatives to allow the parents to go to work (Rawson 2003a, 254). The mechanism of *S. mutans* transmission indicates that Romano-British mothers and primary care givers pre-chewed or tasted their infants' foods, and shared utensils with them when administering food or drink (Fildes 1986, 34). This in turn implies that those looking after the children had caries themselves. Soranus discouraged pre-chewing foods (Temkin 1991, 117-118), however caries in weanlings and the fact that he warned of the practice suggest that this might not have been out of the ordinary. For comparison, true prevalence rates for caries in adult females have been calculated for Cannington at 5.4% (Brothwell et al. 2000, 251), Butt Road, Colchester at 3.9% (Pinter-Bellows 1993, 83) and Bath Gate, Cirencester at 5.4% (Wells 1982, 146) as these reports give numbers of erupted teeth by sex. The adult female rates are higher than those observed in the non-adults of all three sites (TPR 0.4% at Cannington, TPR 1.8% at Colchester and TPR 1.0% at Cirencester). The lower rate in the non-adults was expected due to the age progressive nature of caries (Moore and Corbett 1973). What is however surprising is the higher rate of caries in the women from Cannington as opposed to Colchester, as this should theoretically also result in a higher rate of infection with *S. mutans* at Cannington, and therefore elevated caries rates in the children. These discrepancies may have arisen due to differences in diet, oral health, fluoride exposure or genetic factors between the children of these two sites, rather than solely the rate of infection with *S. mutans* (Sreebny 1983; Woodward and Walker 1994).

The presence of decay in the deciduous dentition in young children also allows us to comment on further implications for health and wellbeing. Caries results in infection and pain, which would have affected the ability of these children to consume food and drink (Gussy et al. 2006). In modern clinical studies, children with early childhood caries exhibit reduced weight and height compared to their peers without severe caries (Azevedo et al. 2005; Clarke et al. 2006). Similar health implications may have affected Romano-British non-adults who suffered from several carious lesions which prevented them from chewing food properly. Caries rates increased until 10.5 years to TPR 2.3%, when the deciduous dentition is gradually replaced by the permanent set of teeth (Hillson 1996, 6). Again, there is a steady rise in caries rates from 10.6-17.0 years from TPR 1.3% up to 1.8%, reflecting its advancement with age.

Without the individual with severe early childhood caries, there is merely a trend for higher rates of caries in the urban children aged 2.6-6.5 years old (X^2=8.57, p<0.05, d.f.=2) (Table 7.2). In children aged 6.6-10.5 years, caries is significantly more prevalent in the major (TPR 3.7%) and minor urban cohorts (TPR 1.0%) compared to no teeth with caries reported from rural sites (X^2=11.36, p<0.005, df=2). The presence of various sugars in the diet of these children plays an important role in the initiation and proliferation of caries (Sreebny 1983; Woodward and Walker 1994). The higher prevalence of caries in these groups not only suggests a higher glucose and fructose intake, but also a prolonged exposure to cariogenic foods during transitional feeding (Veerkamp and Weerheijm 1995; Berkowitz 2003; Freeman and Stevens 2008). Neither human breastmilk nor cow's milk are very cariogenic, their caries promoting properties are however significantly increased when the infant is fed supplementary foods rich in sugars, which would have been the glucose in carbohydrates or fructose in fruits and honey (Moynihan 2000; Azevedo et al. 2005; Kawashita et al. 2011). If the feeding vessels found at Colchester and London were indeed used for bottle-feeding, it would suggest that weanlings may have been bottle-fed in urban Romano-British settlements (Fildes 1981; Eckardt 1999). In turn, bottle-feeding enables the administration of sweetened fluids at high frequency, which is a caries-promoting habit (Seow 1998; Hallet and O'Rourke 2003; Azevedo et al. 2005; Freeman and Stevens 2008; Nissan and Khoury-Absawi 2009). Caries lesions remain more frequent in major urban and minor urban children from 10.6-17.0 years, at almost four times the rate reported from rural sites. Apart from diet, these differences in dental health may also reflect sociocultural differences between those living and working in the countryside as opposed to the towns. Touger-Decker and van Loveren (2003) argued that historically, caries prevalence tends to rise in affluent periods with greater access to sugars and a switch from mainly starchy foods to more refined carbohydrates. At the same time, higher status groups would have had greater access to protein with a reduced reliance on carbohydrates for meals (King 1984; 1999; 2001; Cummings 2009; Griffin and Pitts 2011). In principle, this would result in a lower caries rate in urban communities. However, the opposite effect is achieved by fine milling of cereals into white flour, and the consumption of honey or syrups (Cool 2006, 77-78; Carreck 2008; Alcock 2010, 29-30; Crane 2013, 251). Honey itself displays antibacterial properties which inhibit *S. mutans* growth, whilst the main sugars in honey, glucose and fructose, are highly cariogenic (Nassar et al. 2012). Whether honey is cariogenic or carioprotective remains debated, although it is accepted that it is overall less cariogenic than sucrose (Bogdanov et al. 2008). However, it would have been the main sweetener in the Roman diet and therefore frequently consumed (Moore and Corbett 1973; Bowman and Thomas 1994, 135; Cool 2006, 67). Grape must was boiled down to make a syrup known as *defrutum*, *sapa* or *caroenum* for sweetening (Cool 2006, 67-68). These were made in either Spain or southern Gaul and required shipping to Britain in distinctive amphorae. Evidence for these in the archaeological record of Roman Britain is scarce and dates mainly to the 1st and 2nd centuries AD. These syrups were therefore either imported in different vessels in the later centuries, became even more difficult to get hold of, or alternatively ceased to be available in Roman Britain (Sealey and Davies 1984; Sealey and Tyers 1989; Monfort 1998). However, *defrutum* could be made from boiling down any fruit juice in lead vessels, and could therefore have been widely available across Roman Britain without importing grape must *defrutum* from Spain or Gaul (Farwell and Molleson 1993, 193; Roberts and Cox 2003, 129). In summary, smooth white flour, honey, and *defrutum*, would have been accessible to higher status individuals, and raised caries levels (Moore and Corbett

1973; Cool 2006, 67). The fact that the majority of carious lesions in both the major urban and minor urban sample were interproximal and occlusal further attests to the presence of monosaccharides in the diet of these children. Higher caries rates in older children past weaning age suggest a persistence of dietary differences between urban and rural children, and is also primary evidence for the foods consumed in older children which has not been validated in textual sources.

There is a moderate to strong relationship (Q=0.75) between caries and enamel hypoplasia. This was anticipated as thinned or defective enamel leaves the tooth more susceptible to carious lesion development (Cook and Buikstra 1979; Williams and Curzon 1986, 208; Duray 1990; 1992, 315-316). The higher rates of enamel hypoplasia observed in major urban non-adults also match the elevated rates of carious lesions in these settlements (see section 7.6). The rate of those with both enamel defects and carious lesions was highest in major urban sites at CPR 5.8% compared to the rural children with a crude prevalence rate of 1.3%. Although the distribution is not significant, high rates of enamel hypoplasia in the groups with higher levels of caries fit well with the caries-promoting function of stress. Stress in the urban children may have elevated salivary cortisol levels which in turn supress salivary immunoglobin A and enable caries bacteria to spread more easily (Boyce et al. 2010). Although a relationship between caries and enamel hypoplasia is apparent in Romano-British children, it is more pronounced in the urban cohorts as opposed to the rural children. A similar finding was made by Garcin et al. (2010) who discussed the presence of enamel defects and caries in 613 non-adults from four early medieval Frankish and Moravian sites. Although caries in individuals with enamel hypoplasia was common, the presence of the former did not dictate formation of the latter as enamel hypoplasia also occurred in individuals without caries. The authors concluded that the formation of caries follows a complex inter-relationship of diet, environment and enamel susceptibility. To conclude, the major urban children may have experienced a higher level of nutritional and environmental stress whilst also consuming a diet with more emphasis on refined carbohydrates and fructose than their minor urban and rural peers. Elevated deciduous caries rates and enamel hypoplasia in major urban non-adults may also suggest that these children may have been soothed with honey or sweetened liquids, maybe even pacified, due to prolonged or more frequent illness in early childhood (Williams and Curzon 1986, 210).

7.5. THE WEANLING'S DILEMMA

Soranus and Galen provide insight to weaning practices and transitional foods given in Rome (Fildes 1986, 34; Temkin 1991, 117; Garnsey 1999, 107; Rawson 2003a, 7-30). Following Soranus (II 46[115]), infants should be given introductory foods from six months, the majority of which were cereal foods (Temkin 1991, 117). Colostrum was to be avoided, and goats' milk was regarded as the most suitable breastmilk substitute (Temkin 1991, 88-90). Nutritional deficiencies would have ensued, either due to insufficient amounts of adequate foods given, or upset to the infant intestine and subsequent inability to absorb nutrients properly (Tomas 2009).

Based on isotopic research (Fuller et al. 2006a; Nehlich et al. 2011; Redfern et al. 2012; Powell et al. 2014), we estimate that weaning was complete at around three years, and supplementary feeding may have commenced as early as six months. However the Italian and Romano-British weaning timetable may have differed slightly. Weaning may have been prolonged with a more gradual cessation of breastfeeding observed at Roman London and Queenford Farm (Fuller et al. 2006a; Powell et al. 2014), as opposed to a very abrupt process at Isola Sacra (Prowse et al. 2005, 2008). Mortality is marginally elevated in 2.6-6.5-year olds in the combined study sample, from 11.4% in 1.1-2.5-year olds to 15.4%, a pattern that is more prominent in the primary study sample from 12.8% to 16.9%. These inclines, although slight, may be a result of the cessation of weaning at roughly three years old, or potentially even later due to prolonged and gradual weaning. It has been suggested by Sellen and Mace (1999) that parental time allocation and childcare measures negatively impact on mortality patterns in pre-industrial societies. Although we rely on Soranus' *Gynaecology* and site-specific isotopic data as a guide for weaning, the specific time during which complementary feeding in Roman Britain would have taken place is highly variable. After all, weaning depends on social organisation, maternal time allocation, quality of the diet and food availability to both mother (wet nurse) and child (Sellen 2001; 2009).

In the primary study sample, both porotic hyperostosis and vitamin C and D deficiencies are highest in children younger than 2.5 years old, especially those aged 1.1-2.5 years (TPR 7.8% and CPR 10.8% respectively). Nutritional deficiencies within these age groups may have been the result of either prolonged breastfeeding or inappropriate weaning foods. Breastmilk loses some of its nutritional value after six months, so adequate supplementation, even during prolonged breastfeeding is paramount (Whitehead and Paul 1984; McDade and Worthman 1998; Fewtrell et al. 2007). Malnutrition and infection prompt weanling's diarrhoea which in turn promotes the former, creating a vicious circle of malnutrition and infection (McDade and

Worthman 1998; Fewtrell et al. 2007). Vitamin C deficiency in weanlings may have been a product of cereal-focussed supplementary foods, cooking or boiling of fresh fruits and vegetables, and the administration of breastmilk by a mother or wet nurse who herself is consuming a restricted diet (Robit et al. 2013). Anaemia may have been prompted by infection, high pathogen load and parasites introduced by a diet low in iron and unhygienic feeding practices (Stuart-Macadam 1985; Oxenham and Cavill 2010).

It has previously been argued that those living in urban Romano-British communities were more inclined to follow Roman paradigms due to more pronounced cultural affiliation with Rome (James 2001, 203; Webster 2001; Mattingly 2004). Redfern and DeWitte (2011a, b) have observed a level of cultural buffering across Roman Dorset, whereby the level of 'Romanisation' was not uniform between and within populations, resulting in differential morbidity and mortality risks. Since weaning is culturally mediated, differing patterns between urban and rural communities should be recognisable in the osteological record if Romano-British society exhibited stages of 'Roman-ness' (Sellen 2001; 2009).

In the primary study sample in 6-12 months olds, mortality is significantly lower in major urban cemeteries. Following Scott and Duncan's (1999b) biometric model, infant mortality is influenced by the nutritional status of the mother, and rural mothers may have been overall less healthy than those living in the towns. There is a possibility that significantly higher rates of infant mortality in rural cemeteries may have appeared due to prolonged breastfeeding without supplementation, as breastmilk loses nutritional value from around six months and cannot meet the demands of the growing child (Whitehead and Paul 1984; McDade and Worthman 1998; Fewtrell et al. 2007). Alternatively, rural mothers may have weaned their children very early, either to be able to return to work or as a consequence to adhering to cultural norms rooted in Iron Age weaning practices. Although studies on infant rearing in the Iron Age are scarce, Jay et al. (2008) demonstrated in their isotopic study of children from 4th to 2nd century BC Wetwang Slack in East Yorkshire that supplementation with animal milk and plant foods occurred very early. However, as discussed in section 7.2, we are restricted by differential burial rites for infants which would have influenced this result.

Enamel defects may be a product of weaning stress by reflecting on feeding habits that do not meet the nutritional demands of the child, coupled with a greater pathogen load (Blakey et al. 1994; Katzenberg et al. 1996; Goodman and Song 1999). In the combined study sample, crude prevalence rates for enamel hypoplasia are significantly higher in major urban non-adults at 17.8% (X^2=28.95, $p<0.001$, d.f.=2). This pattern is further magnified in the true prevalence rates for enamel defects in the 2.6-6.5 year age group in the primary study sample, where significantly more children in the major urban sites showed lesions (7.5%, X^2=16.51, $p<0.001$, d.f.=2). It is therefore indeed probable that the higher rate of enamel defects within young children in urban environments have arisen due to very 'Roman' feeding and weaning habits. Additionally, there is an interesting statistical difference in the distribution of cribra orbitalia in the 1.1-2.5 year age group of the primary study sample, with significantly higher rates in the rural sample (64.3%; X^2=15.28, $p<0.001$, d.f.=2). The formation of cribra orbitalia in this age group was expected based on previous research on Romano-British weaning practices and literary sources on Roman transitional feeding (Katzenberg et al. 1996; Gowland and Redfern 2010; Lewis 2010). However, a variety of physiological characteristics of the lactating women, and behavioural alterations to breastfeeding, weaning and child feeding practices by the mother, wet nurse or other main care giver can negatively affect the wellbeing of the child, not just the regime suggested by *Soranus* or *Galen* (Fildes 1986, 34; Temkin 1991, 117; Katzenberg et al. 1996; Garnsey 1999, 107; Rawson 2003a, 126; Robit et al. 2013). The result may suggest that women who breastfed their children in rural Roman Britain experienced compromised health and were under nutritional and environmental stress themselves (Katzenberg et al. 1996). Health differences in rural as opposed to urban weanlings are also apparent when considering the proportionately higher rates of porotic hyperostosis in rural 1.1-2.5 year olds at TPR 22.2% compared to 5.7% in the major urban children, although these differences are not significant. Statistically higher rates of scurvy are also apparent in the rural cohort at CPR 12.5% compared to none reported from major urban sites (X^2=7.47, $p<0.01$, d.f.=2). Weaning practices or foods would have therefore differed between town and country, negatively impacting on the health of weanlings in the countryside. Scarcity of suitable foods may have been either out of choice or necessity, informing on sociocultural identities of the mothers in rural environments on the one hand, whilst also suggesting economic pressures on the rural population on the other. Unfortunately the data cannot distinguish these any further. Isotopic work on mothers and young children from rural sites is desirable to shed more light on how weaning practices might have differed between town and country, and to what extent the overall health and nutritional status of the mothers influenced their children (Beaumont et al. 2015).

7.6. EVIDENCE FOR STRESS IN THE ROMANO-BRITISH CHILDREN

Exploring health and disease in the past is always limited by the study sample being a cohort of non-stationary and heterogenous non-survivors who cannot reflect the exact health status of the living population (Ortner 1991; Wood et al. 1992). Despite this caveat, statistical analysis of non-adult morbidity within the different age groups in Roman Britain still reveals valid information on health and disease in the province (Wright and Yoder 2003; Klaus 2014; Wilson 2014). It is important to bear in mind that the terms 'health' and 'stress' are not synonymous (Reitsema and McIlvaine 2014; Temple and Goodman 2014). The World Health Organisation has defined health as a state of complete physical, mental and social wellbeing, and it is not simply the absence of disease or infirmity (WHO 1999, 10). We therefore cannot assume who was *healthier* or *unhealthier* in an archaeological population based on the quantification of presence and absence of skeletal lesions in a population of non-survivors (Reitsema and McIlvaine 2014; Tanner and TAPS Bolivia Study Team 2014; Wilson 2014). However, we can quantify stress as specific disruptions of the body's physiological balance, which does not allow us to measure the systemic biological stress specifically, but its consequences (Huss-Ashmore et al. 1982; Klaus 2014).

Due to the nature of the data, only crude prevalence rates are reported for the combined sample, with overall percentages recorded as: cribra orbitalia (10.6%), enamel hypoplasia (14.2%), metabolic disease (9.3%), and non-specific infection (13.4%). The overall rate of pathology is significantly higher in urban sites compared to the rural cohort (X^2=13.00, $p<0.001$, d.f.=2). This pattern correlates with the level of urbanisation, which is proven to have had a detrimental effect on non-adult and general population health in past societies (Rose 1976; Addyman 1989; Lewis 2002c, 2010).

In both the combined and primary study sample, crude and true prevalence rates of enamel hypoplasia were significantly higher in major urban non-adults (CPR 17.8%; TPR 11.4%) compared to both minor urban (CPR12.3%; TPR 9.6%) and rural individuals (CPR 5.9%; TPR 4.5%) (CPR: X^2=28.95, TPR: X^2=43.66, $p<0.001$, d.f.=2). This is perhaps not surprising given the literature outlining the adverse health effects of urbanisation on child health, and Romano-British urbanism in particular (Gowland and Redfern 2010; Lewis 2010). Lower rates in the rural groups may suggest that fewer children survived the stress leading to enamel defects, rather than reflecting better health during their growing years, and this needs to be explored by looking at mortality rates (Wood et al. 1992, 2002; Klaus and Tam 2009). There is a trend in mortality of children aged 1-4 years old between urban and rural sites (X^2=8.96, $p<0.05$, d.f.=2), where mortality is lowest in major urban cemeteries (16.8%), compared with

18.9% in rural sites and 25.5% in minor urban settlements. Perhaps there was a shift from survivable stresses in the major urban settlements to more frequent fatal health insults in more rural settings.

Apart from non-specific nutritional and environmental stress, enamel hypoplasia can also result from psychological or emotional stress (Roberts and Manchester 2010, 222). Living in densely populated, busy and loud urban environments may have contributed its share to the higher rates of hypoplastic defects in the teeth of children from urban sites. Enamel defects can also be the product of weaning stress due to breastfeeding habits and patterns in transitional feeding that do not meet the nutritional demands of the child, and reflect a greater pathogen load coupled with multiple environmental stresses (Blakey et al. 1994; Katzenberg et al. 1996; Goodman and Song 1999).

Enamel defects in the deciduous dentition were only observed in major and minor urban non-adults at true prevalence rates of 2.4% (n=26/1064 observable deciduous teeth) and 1.5% (n=20/1346 observable deciduous teeth) respectively. A total of 46 deciduous teeth have been recorded with circular hypoplastic lesions on the tooth enamel, 82.6% (n=38) of these were on the deciduous canines which normally account for a large portion of enamel hypoplasia in the deciduous dentition (Lukacs 1991). Only bilateral enamel defects in the deciduous dentition have been taken into account here, and according to Skinner and Hung's (1989) appraisal of circular enamel defects on the deciduous canine are a result of minor trauma. Reduced cortical bone over the canine crypt in infants elevates the risk for enamel defects on the canines secondary to minor injuries sustained in normal motor development. The aetiology of these defects suggest weakened bone structure due to compromised calcium levels, either induced by the weaning foods given or the breastmilk of a mother who herself has a low calcium intake. Localised hypoplasia on the deciduous canine is therefore associated with compromised infant health and in-utero stress which is indicative of poor maternal health (Halcrow and Tayles 2008b).

In the permanent teeth, true prevalence rates of enamel defects were also significantly higher in the urban assemblages (X^2 =39.12, p<0.001, d.f.=2), for both anterior (X^2=13.8, p<0.001, d.f.=2) and posterior teeth (X^2=37.16, p<0.001, d.f.=2). Therefore it is not only stress in early childhood that differs between urban and rural children, but also in later stages, up until the age of crown completion of the second molar at around eight years of age. The differential rates of hypoplastic defects in the posterior teeth may signify continued nutritional pressure and depressed health status in the minor urban children, which would be expected to affect children living in the larger towns. However, the higher rate of hypoplastic defects in the urban children are witness to survived episodes of stress, signifying a stronger and more resilient population in the towns.

Children dying in the 10.6-14.5 year age category of the primary study sample had the highest rates of enamel defects at 16.7% (X^2=176.61, p<0.001, d.f.=4). This was unexpected, as it was anticipated that younger individuals would be affected by higher levels of non-specific stress and morbidity as they adapted to their environment. This group represents individuals resilient enough to live until later childhood, when a new set of environmental and biological stressors eventually increased their mortality risk. This may also be a cohort that was chronically stressed, not just in early childhood, and ages-at-death accumulated between 10.6-14.5 years. This is in keeping with the 'Barker Hypothesis' which attests that illnesses in later life often have a fetal or early childhood origin (Armelagos et al. 2009). Although Armelagos et al. (2009) referred to illness in older adults, this observation can still be relevant for non-adult morbidity and mortality. Interestingly, both crude and true prevalence rates of enamel defects are low in the rural cohort until 6.5 years old, with a surge in 6.6-10.5-year olds to CPR 62.5% and TPR 14.3% (compared to CPR 33.3% and TPR 13.6% in major urban non-adults). From 10.6 years and older, the rates decline again, and remain (significantly) lower than in the major and minor urban cohorts. The elevation of hypolasia in 6.6-10.5 year olds demonstrates that early childhood stress was indeed present in rural Romano-British children, and within this age group had a similar effect on mortality as it did in those from major urban cemeteries. A greater physical demand may have been placed on rural children from the age of 6.6 years, and those who experienced stress in early childhood would have been exposed to a higher mortality risk.

On average, the children with macroscopically visible enamel hypoplasia in minor urban and rural sites lived statistically longer than those without. The mean age-at-death difference was increased in minor urban cemeteries to 3.86 years (KS=2.2, p<0.001), and widened further to 5.49 years in the rural sample (KS=2.032, p=0.001). Recovery from early childhood stress may have been more difficult in urban environments, hence the non-survivors with enamel hypoplasia died soon after their frailer peers who perished younger (Cook and Buikstra 1979; Goodman and Armelagos 1988; Katzenberg et al. 1996). The mean age difference of nearly 5.5 years between non-survivors with and without enamel hypoplasia in the rural cohort may be a product of better recovery from early childhood stress, and overall a lesser incidence of enamel hypoplasia.

7.7. RISK OF INFECTION

7.7.1. Endocranial lesions

The precise aetiology of endocranial lesions remains disputed. For the purposes of this study, endocranial lesions are interpreted as resulting from inflammation or haemorrhaging of the meninges secondary to infection. Bearing in mind the limitations of this approach, vitamin deficiencies, trauma and rapid new bone growth during early childhood must not be disregarded (Lewis 2004; Zahareas 2011).

Lesions on the internal aspects of the skull were recorded in 9.9% of children in the primary study sample that presented with cranial vaults. Type 3 (vascular impressions of capillary lesions with some new bone formation) was most commonly recorded at 31.7%, although the distribution is not significant. The highest frequency of endocranial lesions was recorded in the 1.1-2.5 year age group at TPR 15.8% of individuals affected, although this was not significant. A total of 55.3% of the individuals displayed active lesions, with 53.8% of those in children under the age of 2.5 years old. In children aged 1.1-2.5 years, 72.2% of those with endocranial lesions showed active as opposed to healing bony changes, which indicates that the inflammation was acute rather than chronic at the time of death. Just under half of the lesions recorded were located on the occipital bone around the cruciate eminence, which is statistically significant (X^2=15.88, p<0.001, d.f.=3). This result was expected as Lewis (2004) attested that lesion formation on the occipital was also the most common in children from medieval and post-medieval sites from England. It was interesting to see that lesions on the parietal bone were most frequent in children aged 10.6-14.5 years at TPR 2.5%, which are most likely to be pathological.

Statistically, the lowest rate of endocranial lesions were found in the major urban sample at 3.6% overall (X^2=16.52, p<0.001, d.f.=2), indicating that meningeal inflammation was more common in less urbanised areas. Elevated rates of endocranial lesions in the minor urban cemeteries might be a reflection of the inclusion of rural individuals in these burial grounds. It is important to bear in mind that the absence of lesions in the major urban sample does not demonstrate an absence of meningeal infections, such as meningitis. Instead, children in major urban sites may not have been able to sustain these kinds of infectious episodes for long enough to develop skeletal lesions and died before the onset of an osteological response (Lewis 2004).

No statistical difference has been found between the average ages-at-death in children with and without endocranial lesions, which is a reminder of the diverse aetiology of these lesions. Similar ages-at-death may be the result of rapid lesion formation and subsequent death in case of meningeal infections, such as meningitis, as a possible aetiology. Alternatively, if endocranial lesions may be linked with rapid growth, no differences in ages-at-death should be seen between affected and non-affected individuals.

7.7.2. New bone formation

Sub-periosteal new bone formation has traditionally been used as an indicator of infections of non-specific origin. This theory has received considerable criticism in the past, and this type of skeletal lesion is therefore taken as indicative of an inflammatory response which can arise from non-specific infection, as well as a range of other disorders, trauma or diseases (Weston 2008; 2012; DeWitte 2014; Klaus 2014).

In the combined sample, crude prevalence rates of non-specific infection are higher in minor urban (20.4%) and rural non-adults (14.5%), compared to their major urban peers (10.5%). This pattern is not significant, and a similar observation was made for the distribution of sub-periosteal new bone formation in the primary study sample (major urban CPR 10.6%, minor urban CPR 19.3% and rural CPR 15.0%). The lack of any distinct patterns between the sites and age groups may be a reflection of the diverse causative agents behind periosteal new bone formation (Ragsdale et al. 1981; Weston 2008; 2012). Alternatively this may also be an indication of similar rates of infection in both rural and urban environments. Although the more reactive non-adult periosteal membrane is more prone to inflammation and tearing, there is also potential for us to not see older lesions as non-adult bone heals and remodels quicker (Wenaden et al. 2005; Lewis 2007, 133). Only 15.4% (n=6) of those affected by periosteal new bone formation showed evidence of healing, a common pattern in non-adult material. This suggests most individuals were experiencing inflammation when they died. No statistical relationship has been found between average ages-at-death in individuals with and without new bone formation across all three site types, which further attests that new bone formation may not always be indicative of infection but can relate to relatively minor injuries.

7.7.3. Tuberculosis and other respiratory infections

Lewis (2011) identified childhood tuberculosis in seven non-adults from Poundbury Camp in Dorset, which marked the first instance of reporting and discussing the disease in Romano-British non-adults. An additional seven new cases of probable and possible tuberculosis have been identified in the primary study sample, and these have not been discussed previously in the literature. Tuberculosis was diagnosed with certainty in three cases including two individuals from Butt Road, Colchester (mean ages of 5.5 and 11.5 years) and one individual from Ashton, Northamptonshire (mean age of six years). These cases are convincingly suggestive of tuberculosis as spinal involvement was evident, two cases possibly presenting a gastrointestinal origin. The remaining four cases of possible tuberculosis are more likely to reflect pulmonary infections such as pneumonia or bronchitis and are discussed below with the remaining eight cases of probable respiratory disease.

It is not until the post-primary or secondary phase of tuberculosis sets in that skeletal changes occur, which requires either re-infection or re-activation of the latent primary tuberculosis as a result of immune system suppression (Nelson and Wells 2004; Roberts and Manchester 2010, 187). The likelihood for developing disease in children after being exposed to and infected by *M. tuberculosis* is higher than in adults, peaking at up to four times the rate in infants. Identifying childhood tuberculosis is particularly informative as it is a reflection of ongoing transmission of the disease within a population. With the three new cases added in this study, detecting childhood tuberculosis is therefore a valuable tool for gauging the prevalence of the disease.

Crowded living conditions, close contact with animals and poor sanitation would have elevated risks for infection, and are considered some of the shortcomings of Romano-British urbanism (Roberts and Cox 2003, 123-125; Hall 2005, 125, 137; Lewis 2011). A compromised immune system would have also aggravated the susceptibility to tuberculosis infection. Modern clinical studies have also established a link between measles and whooping cough with an elevated risk for tuberculosis (Nelson and Wells 2004). A poor nutritional status also affects the onset and severity of the disease (Pfeiffer 1984), with air pollution generally promoting respiratory ailments (Roberts 2007).

In the current study, a further 13 non-adult individuals in the primary study sample were identified with new bone formation on the visceral aspects of their ribs. Some of these individuals also display more widespread evidence for infection but lack diagnostic lesions that are pathognomonic or strongly suggestive of tuberculosis (Pott's disease or dactylitis). The highest number came from major urban sites (69.2%, n=9). The majority of these cases mark active new bone formation indicating the pulmonary infection was acute and ongoing at the time of death (Pfeiffer 1991). The nature of inflammation of the visceral periosteal rib surface is non-specific, and we cannot ascertain the cause or mechanism of infection. The underlying aetiology may range from tuberculosis to bronchitis, pneumonia or neoplastic disease (Roberts and Buikstra 2003, 105). Roberts and Cox (2003, 113-114) reported rib periostitis at a crude prevalence rate of 2.1% in Roman Britain. The 13 cases of respiratory disease identified in the primary study sample add weight to the hypothesis of significant amounts of time spent in polluted low quality air, applying to both urban and rural Romano-British settlements. In urban environments, this may give indication of bad ventilation in living quarters, as well as industrial waste (Hall 2005; Lewis 2011). Rural dwellings may have also been affected by smoke of the hearths and therefore particle-polluted air with lower oxygen content (Roberts and Manchester 2010, 18).

7.8. HUNGER OR BAD HABITS? EVIDENCE FOR METABOLIC DISEASE

7.8.1. Cribra orbitalia

Given recent research into the aetiology of these lesions, cribra orbitalia was interpreted as a general indicator of poor nutritional status, perhaps due to a high pathogen load, parasitic infections, and diarrhoeal disease (Holland and O'Brien 1997; McIlvaine 2013; Mahmud et al. 2013). Although genetic haemolytic anaemia was not ruled out (Walker et al. 2009; Lewis 2012), it was only considered when other pathognomonic traits were observed. A crude prevalence rate of 10.6% was reported in the combined sample, with no statistical differences evident between the site types. In the primary sample, 20.4% of individuals with at least one orbit present had cribra orbitalia, but differences between major urban and rural sites were not significant (rural TRP 27.7%; major urban TPR 6.1%, $X^2 = 5.74$, $p<0.05$, d.f.=1).

The majority of lesions (76.2%) were active at the time of death, indicating that these children were suffering from a chronic health insult leading up to their death which rendered them unable to remodel the lesion (Stuart-Macadam 1991; 1992). Healing of lesions was observed in 5.4% of urban children and only 0.9% of rural children, however the distribution of healed lesions by age was not statistically significant. Active lesions were more prevalent in rural children, although not statistically at the 99.9% level ($X^2=10.28$, $p<0.01$, d.f.=2). Nevertheless, this trend may indicate that chronic health insults were more likely in rural environments. It may also potentially validate that nutritional stress, infections, and high bacterial or parasitic pathogen load were acting more on rural children (Stuart-Macadam 1991; Holland and O'Brien 1997; Wapler et al. 2004; Djuric et al. 2008; Walker et al. 2009; Oxenham and Cavill 2010). These distributions confirm the hypotheses of Griffin and Pitts (2012) for Roman Britain as a whole, and Redfern et al. (2015) for Roman Dorset, who attested elevated stress in rural populations. If we assume that a substantial portion of the cribrotic lesions in the Romano-British children resulted from iron-deficiency anaemia and megaloblastic anaemia, we are faced with some promising new insights. Iron and vitamin B6 and B12 are mainly obtained from the same food sources including red meat, pork, poultry, seafood, oatmeal and some vegetables (Baker et al. 2010; NHS 2015a). Previously published literature on dietary variability in Roman Britain attests that the consumption of plant foods, meat and fish was not uniform across the social strata, and animal foods, especially meat were less accessible to lower status individuals (King 1984; 1999; 2001; Molleson 1992; van der Veen 2008; van der Veen et al. 2007; 2008; Cummings 2009; Müldner 2013). If animal products were indeed less available to lower status individuals as attested by zooarchaeological and isotopic studies, the higher incidence of cribra orbitalia in rural non-adults is suggestive of their lower status. Although oats were widely cultivated across Roman Britain, oatmeal itself was mainly reserved for animal fodder and only eaten occasionally (Cool 2006, 71; Britton and Huntley 2011). Even considering that oatmeal was consumed more regularly among lower status adults and children, if the child suffered from a parasitic infection or diarrhoeal disease, the loss of nutrients would have presented an elevated risk for iron and vitamin B6 and B12 deficiencies when meat and fish were scarce (Holland and O'Brien 1997; Facchini et al. 2004; Mahmud et al. 2013). To date, four individuals with calcified tapeworm cysts have been reported in the literature (Wells 1976; Roberts and Cox 2003, 124-125), and eggs of whipworm and roundworm have been identified in the stomach area of some gypsum burials at Poundbury Camp (Jones 1993b, 197-198). In Roman York, further evidence for whipworm and roundworm ova was reported from a sewer and a well which may have contained human excrement (Wilson and Rackham 1976, 32-33; Kenward et al. 1986, 263; Roberts and Cox 2003, 125). Roberts and Cox (2003, 125) have also remarked on the possibility of human faecal material having been used for manuring during the Roman period, which would further spread intestinal parasites and elevated infection risks. More research into intestinal parasites in Roman Britain is desirable to further elude to the type of species present and how widespread these infestations were. So far, the main body of evidence stems from major urban sites, but there is no reason to presume that the rural population would have been parasite-free, as hygiene would have been on the same par as in urban environments or maybe even lower. Lastly, a cereal-based diet also introduces excessive amount of phytates which inhibit the intestinal absorption of iron and may exacerbate chronic iron-deficiency anaemia (Facchini et al. 2004; Nielsen et al. 2013).

Within the primary study sample, the highest frequency of cribra orbitalia was in the 2.6-6.5 year age group at 40.2%, which is statistically significant (X^2=39.71, $p<0.001$, d.f.=5). Within this age group, the majority of lesions were active at the time of death, with a statistically significant rate of 74.3% (X^2=16.57, $p<0.001$, d.f.=1). An increase in active lesions within this age group may reflect the adverse health consequences after the cessation of breastfeeding and a greater pathogen exposure secondary to increased mobility and interaction with other people, animals and the environment (Sheridan 1991; Weisner 1996; King and Ulijaszek 1999, 177; Malina 2004; Lewis 2007, 6). This peak also concurs with the time for the onset of growth faltering at five years old compared to post-medieval children (see section 7.3.1). In 1.1-2.5-year olds, rates of cribra orbitalia are significantly higher in the rural children (TPR 64.3%; X^2=15.28, $p<0.001$, d.f.=2), and this is a re-occurring trend in 6.6-10.5-year olds when compared with the major urban cohort (rural TPR 66.7%, major urban TPR 20.8%; X^2 =4.53, $p<0.05$, d.f.=1). The distribution in the 1.1-2.5 year age group was unexpected, and is discussed in section 7.5 on evidence for weaning practices, similarly the trend in the 6.6-10.5 year age group is discussed in section 7.12 with reference to adolescence and the working lives of Romano-British children.

Overall, non-adults with cribra orbitalia lived significantly longer than those without, confirming the assumption that those able to sustain lesions were more resilient towards external stresses than those without across all three site types (Wood et al. 1992).

7.8.2. Vitamin C and D deficiencies: no fresh fruit or sunlight?

In the combined study sample metabolic disease was recorded in 9.3% of individuals, including rickets and scurvy, osteopenia and porotic hyperostosis, with a trend towards lower rate of metabolic disease in the minor urban sample (CPR 6.6%; X^2=6.56). A similar overall rate of 9.5% was reported in the primary study sample, and interestingly, metabolic disease was recorded most frequently in children from rural sites at a rate of 13.4%, compared to CPRs around 8.0% in urban sites. However, the distribution lacks statistical significance. This result may indicate that nutritional deficiencies and metabolic disturbances affected Romano-British children to a similar degree, regardless of their living environment. Given the current knowledge on Romano-British urbanism as a detrimental living environment, this is surprising (Roberts and Cox 2003, 123-125; Lewis 2010). The lack of a statistical relationship indicates that the rural environment was not a significantly better one to live in, whilst also demonstrating that both large and small towns were not posing a significantly higher risk for metabolic disease in children. Due to the nature of the secondary skeletal data, there are some caveats to the interpretation of these patterns. Sub-periosteal new bone formation and endocranial lesions are frequently noted as indicators for non-specific infection (Lewis 2004; Weston 2008), and new bone deposits or endocranial lesions can also occur in conjunction with metabolic disorders (Ortner and Erickson 1997; Ortner and Mays 1998; Lewis 2004; Brickley and Ives 2006). Differentiating between these lesions as a consequence of infection or metabolic disease could only be ensured in the primary study sample, as the methods for recording pathological lesions in non-adult skeletons are continuously evolving.

Where ever possible, it was sought to distinguish scorbutic from rachitic lesions in the primary study sample, however in some instances both conditions may have been present in the same individual, or preservation interfered with making a clear distinction due to similar skeletal changes (Brickley and Ives 2008, 113-114; Geber and Murphy 2012; Mays 2014). A certain degree of co-morbidity of rickets and scurvy in Romano-British non-adults is a given as both are diseases of malnutrition (Brickley and Ives 2008, 113-114; Klaus 2012). Co-morbidity of vitamin C and D deficiency only affected two individuals aged 1.1-2.5 years, from a minor urban and a rural site. The sample is too small to undergo meaningful statistical analysis. However these finds in the 1.1-2.5 year age group agree with modern clinical studies that attest a peak in rickets between four months to four years of age, and the development of scurvy in relation to weaning (Buckley 2000; Ortner 2003, 393; Brickley and Ives 2008, 45).

Children that exhibited metabolic disease were on average younger at death than those without rachitic and scorbutic lesions, however the age differences are not statistically significant. Although in major and minor urban sites, the mean age difference of around three years falls just shy of statistical significance at the 99.9% with KS=1.749, p=0.004 and KS=1.822, p=0.003 respectively. This result may indicate that rickets and scurvy did not significantly contribute to mortality in the rural children, perhaps indicating that these children suffered from chronic nutritional deprivation. In children from urban sites however, metabolic disease would have compromised longevity, possibly a reflection of very acute disease states.

7.8.2.1. Rickets

The inadequate mineralisation of bone seen in rachitic lesions is a consequence of disturbances in calcium absorption secondary to vitamin D deficiency, or in some cases low calcium intake. Vitamin D is a prohormone, which is synthesised in dermal cells when exposed to sunlight, and depleted levels lead to insufficient calcium absorption and ultimately weakened bone structure (Mays 2008, 216; Roberts and Manchester 2010, 238; Shin et al. 2010). Finding rickets in archaeological populations allows us to make inferences on dress, where children were covered up and shielded away from the sun, childcare practices that mainly took place indoors, and the environment, for example fog or polluted air and narrow dark streets in built-up towns (Lewis 2002a, 55; 2010; Mays et al. 2006; Brickley and Ives 2008, 263; Pettifor 2014).

In modern populations, the prevalence of rickets is highest in infants and young children aged 3-18 months, as vitamin D stores in the infant are diminished six months after birth and need to be replenished via exposure to sunlight (Pettifor and Daniels 1997; Foote and Marriott 2003). Calcium deficiency resulting in rickets is normally seen after two years as a result of weaning and supplementary feeding (Thacher 2006). Similar to scorbutic lesions, we currently do not know how much time elapses between the onset of vitamin D deficiency or depleted calcium stores. We therefore have to assume that the actual rate of vitamin D deficiency and inadequate calcium intake may have been higher in Romano-British children than the rate that can be osteologically discerned. Additionally, signs of rickets cannot appear if a child suffered from starvation, as for example severe protein-calorie deficiency will inhibit rachitic symptoms (Adams and Berridge 1969; Salimpour 1975).

In the primary study sample vitamin D deficiency affected 2.6% of non-adults overall. No statistical trend was found in the distribution of rickets between the site types and ranged from 2.2% in minor urban sites to 3.4% in rural children. There is a trend for a higher incidence of rickets in younger individuals, reflecting its aetiology as an early childhood disease (Pettifor 2003, 544; Urnaa et al. 2006). The highest frequency of rachitic individuals was found in infants aged 6-12 months (CPR 8.2%). A high rate of rickets within this age group was not unexpected as existing vitamin D stores are depleted within six months and need to be replenished by exposing the infant to sunlight (Pettifor and Daniels 1997; Foote and Marriott 2003). Infants and young children may have experienced similar child rearing and feeding practices across Roman Britain which either left them deficient in calcium or shielded them away from sunlight for prolonged periods. Swaddling, as recommended by Soranus (II 14[83]) may have been a universal practice, and not just followed by primary caregivers in the more Romanised towns, as suggested for Roman Dorchester (Temkin 1991, 84-87; Lewis 2010). Although frequently associated with rickets in infants and young children in the palaeopathological literature, swaddling may only have a marginal impact on vitamin D deficiency and mainly promote child wellbeing. Instead, the development of rickets may be more strongly linked with a low socioeconomic status that promotes compromised nutrition and behaviours that limit sun exposure (Urnaa et al. 2006; van Sleuwen et al. 2007). Children may have been kept indoors during their younger years in crowded living quarters in the towns, perhaps because there was simply no outdoor space, or it was easier to look after them in the house or apartment, and accidents on the busy roads and alleyways could be avoided. Parents and primary caregivers may have exhibited similar behaviours in rural settlements. Additionally, mothers who took their children to work in the field may have covered them up and carried them in a sling which shielded away sunlight. Soranus (II 45[114]) also recommended wrapping infants up in clothes once they start to sit up (Temkin 1991, 116). This practice was probably intended to help support the trunk, but ultimately lowered the skin's exposure to sunlight. However, Pettifor and Daniels (1997, 665) stated that even fully clothed infants only need two hours of sunlight a week to maintain healthy bone structure. With this in mind, some of the rachitic infants and young children may have been generally poorly. By keeping them indoors to recover and rest, vitamin D deficiency may have ensued, possibly exacerbated by low calcium levels in the diet, prolonged breastfeeding, and/or gastrointestinal maladies that limited calcium absorption in the small intestine such as weanling's diarrhoea (Pettifor and Daniels 1997; Buckley 2000; Foote and Marriott 2003).

7.8.2.2. Scurvy

The first signs of scurvy can develop within six months of vitamin C deficiency (Maat 2006), although the rapid growth in non-adults and especially infants can lead to an earlier onset of haemorrhaging (Brickley and Ives 2006; Mays 2008, 223). Yet the timing of skeletal involvement following the onset of deficiency is unclear (Crandall and Klaus 2014). New research on scurvy in archaeological non-adult skeletons has uncovered exciting new insights into the aetiology of vitamin C deficiency. Scorbutic lesions may not only indicate a dietary deficiency of foods containing vitamin C such as fresh fruits and vegetables but also more widespread under- or malnutrition (Crandall and Klaus 2014). Apart from straightforward dietary deficiencies, Stark (2014) described skeletal evidence for scurvy as a vehicle for exploring food insecurity, preferential feeding and subsistence economy. Halcrow et al. (2014) considered causes that affect the vitamin C levels in the body, including reduced intake, increased requirements, malabsorption or genetic causes that impact on vitamin C status. Especially in young children, fussy eaters, religious dietary practices, low socioeconomic background, neglect, infection, inflammation, anaemia, gastrointestinal diseases and infections, and deficiencies in the pregnant and breastfeeding mother have to be considered (Clark et al. 1992; Buckley 2000; Popovich et al. 2009; Holley et al. 2011; Lahner et al. 2012; Halcrow et al. 2014).

In the primary study sample scurvy affected 2.2% of children. The distribution between the sites is statistically significant (X^2=13.82, p<0.001, d.f.=2), with more scorbutic children on rural sites (CPR 6.9%), compared to major urban (CPR 1.2%) and minor urban settlements (CPR 0.9%). Scurvy was equally likely to occur in any age group, as no statistical trend was found in the age distribution of scorbutic lesions, although the 1.1-2.5 year age groups exhibits the highest crude prevalence at 2.2%. Unlike rickets, scurvy is therefore not solely a product of early childhood feeding and rearing practices. Vitamin C deficiency was a threat to children of all ages, particularly in the countryside. In principle, access to adequate foods should be plenty in rural settings, however the skeletal evidence suggests shortages. The NHS recommends a daily intake of 40mg per day for adults (NHS 2015b), but more is required in infants and children, and women during pregnancy and lactation (Brickley and Ives 2008, 48; National Institutes of Health 2011). Vitamin C deficiency can be prevented by ingesting small amounts of ascorbic acid as clinical symptoms only start to develop once less than 10mg per day are available (Hodges et al. 1971; Stark 2014). A minimum intake of over 10mg per day is covered by consuming small amounts of fruits and vegetables, such as a cup of leek, parsnip, onion or pear (USDA National Nutrient Database 2013). It is therefore surprising that scurvy occurred at a higher rate in rural children, which prompts us to consider more widespread resource stress perpetuated by political and economic factors in rural settings as opposed to simply a restricted diet (Klaus 2012; Crandall 2014). Scurvy can heal swiftly once appropriate amounts of vitamin C are consumed again. Pimentel (2003) stated that clinical symptoms will improve within two weeks after daily ingestion of 200mg of ascorbic acid, although skeletal lesions may take years to remodel entirely (Parfitt 2002; 2004). All but one case of scurvy recorded in the rural children were active at the time of death (92.3%). This suggests a chronic state of nutritional deficiency in the rural children, possibly perpetuated by a number of factors rather than just a lack of appropriate foods. Although Roman cuisine involved the boiling and cooking of fruits and vegetables, certain foodstuffs were also recommended to be eaten raw or unprepared and we cannot simply blame cooking habits on higher scurvy prevalence. If the population in the countryside was mainly concerned with having to provide for the urban population and army, a substantial portion of produce would have been reserved for trade and taxes (Scheidel and von Reden 2002; see section 7.14). Considering the possibility of a manorial or otherwise exploitative system of landownership and tenancy (de la Bédoyère 1993, 86; Jones 1996, 208), the peasant families may have lived in oppressive conditions compromising their diet, mental and physical wellbeing. Land would have been distributed to peasant farmers in late Roman Britain, based on the renewal of an annual lease. By the 4th century however, tenants became legally tied to the estate and land tenancy became hereditary. This made the process of taxation easier to oversee whilst also relieving the land owner of having to provide food and accommodation to the workers (de la Bédoyère 1993, 86). Bonded workers would therefore not only have been customary to late Romano-British *villae*, but tenancy would have also affected the farmers in villages outside of *villa* estates (de la Bédoyère 1993; 74-75; Jones 1996, 208-215). The malnutrition we are observing in Romano-British children from rural sites may be a result of oppressive landownership which affected food security and distribution in the countryside (Crandall 2014). Social change and status differences inherently affect the foods people have access to, and differences may have been pronounced in Roman Britain, affecting those at the bottom of the social ladder most profoundly (Armelagos et al. 2014). It is important not to confuse the mal- or undernutrition seen with starvation (Mays 2014). Ascorbic acid would have been present in the diet of these children, albeit at too low a level, in order for skeletal tissues to form new bone and initiate bony changes (Crandall et al. 2012; Stark 2014). Rural children therefore did not experience starvation but rather a restricted diet. We cannot know to what extent these children suffered hunger, but we do see that their diet was not sufficiently varied. Two age groups stand out further by showing statistical trends in the distribution of scurvy across the sites: children aged 1.1-2.5 years old, and children of 10.6-14.5 years. Within these age groups, rural children are more likely to exhibit scorbutic lesions than elsewhere in the sample, with rates of 12.5% (X^2=7.47, p<0.01, d.f.=2) and 10.0% (X^2=7.25, p<0.05, d.f.=2) respectively. Within the younger age group, deficiencies may have arisen due to general food shortages available to the family, and resource distribution would have favoured adults and older children, resulting in inappropriate weaning foods given. Alternatively, mothers in rural environments may have ceased breastfeeding earlier than the isotopically ascribed three years, leaving the child more susceptible to nutritional deficiencies. Alternatively, mothers and primary caregivers may have held the false belief that all fruits and vegetables given to young children must be boiled or otherwise cooked which lowers their nutritional value.

The trend for higher scurvy rates in the 10.6-14.5-year olds is surprising. This is an unexpected result as children approaching and going through puberty should be in good health. We also have to consider the sample sizes available for this age group, as no cases of scurvy have been recorded in major urban and minor urban settlements, and only two possible cases from rural cemeteries. Both of these display cranio-facial lesions only. One of these adolescents exhibited possible healing scurvy and therefore mirrors an episode of deprivation in earlier years. These individuals may have been exceptions rather than the rule, although we may assume that hard labour and inadequate foods may have taken their toll on these children.

What is generally of interest is that there is a greater dispersal of scurvy across the ages in the rural sample which may indicate common shortage of adequate foods to children in the countryside. All of the rural children with possible scurvy aged 2.6 years and older stem from Cannington in Somerset. The deprived nutritional status of the children and adolescents at Cannington may be linked with possible site characteristics of quarrying and large-scale organised exploitation of the land for farming. Apart from co-morbidity of scurvy with rickets, anaemia is also often linked with a deficiency in vitamin C (Besbes et al. 2010).

Cribra orbitalia Grades 3 and 4 were recorded in five (38.5%) of the 13 non-adults with scorbutic lesions, and co-morbidity ranges from 25.0% (n=2) in rural children with scurvy to 33.3% (n=1) in the major urban sample, and 100% (n=2) in scorbutic children from minor urban cemeteries. Cribra orbitalia co-occurring with scurvy indicates more general mal- or undernutrition in the children, rather than solely a lack of ascorbic acid. Scurvy in Roman Britain may therefore not only be a skeletal manifestation of vitamin C scarcity, but should also prompt us to consider a lack of other essential nutrients and minerals.

7.9. THALASSAEMIA

One of the objectives of this research was to assess the presence of thalassaemia in Romano-British non-adults, in response to its identification in children from Poundbury Camp (Lewis 2012). Definitive cases are difficult to identify. Although the 'rib-within-a-rib' feature is pathognomonic, the disease has not received much attention in the anthropological literature to aid its identification in non-adult remains. To date, the one probable and two possible cases of thalassaemia at Poundbury Camp mark the only instance of the disorder found in Romano-British non-adults. At Lankhills in Winchester, Clough and Boyle (2010, 389-390) described a young child aged four months to two years with probable rickets and anaemia, and suggested infantile cortical hyperostosis as a differential diagnosis. According to the authors, radiographs were taken but not included in the skeletal report, and it would be of interest to re-analyse this individual for thalassaemia.

In the primary dataset, thalassaemia is suggested as a possible differential diagnosis for two infants from the cemetery at Kingsholm, Gloucester, and a probable diagnosis for a young child at Butt Road, Colchester with localised rib pathology (Lagia et al. 2007; Lewis 2012). If the child at Colchester (skeleton 145) was suffering from β-thalassaemia, it would suggest that the parents were migrants from a region where the disease is endemic, such as the Mediterranean (Lewis 2012). Migration across the Roman Empire has been validated both osteologically and isotopically, confirming immigrants in York (Leach et al. 2009; 2010; Müldner et al. 2011), London (Montgomery et al. 2010), Gloucester (Chenery et al. 2009) and Dorchester (Lewis 2012), and on the continent in Bavaria (Schweissing and Grupe 2003).

Skeleton 145 was recovered from the formal cemetery, and no information on any unusual burial customs or grave goods was given. So far no studies have been published that investigate the isotopic signatures of Romano-British skeletons from Colchester. The late Roman cemetery at Butt Road is considered a managed one, which may indicate an early Christian following at the site (Crummy 1993b; Crummy and Crossan 1993; Watts 1993).

One adult female had been buried wrapped in a shroud of silk which may have been imported from China (Crummy 1997, 120-121). These findings may imply high status, non-local individuals. The lack of distinction in the burial archaeology of skeleton 145 may demonstrate that the family were integrated members of society in Romano-British Colchester, who were not considered as particularly unusual.

7.10. TRAUMA

Roberts and Manchester (2010, 151) reported trauma in 10.7% of Romano-British adults who have been mainly recovered from urban cemeteries. In the non-adults from Poundbury Camp, Lewis (2010) reported a true prevalence rate of 5.4% for rib fractures, in addition to one infant of around seven months old with a metaphyseal bucket-handle fracture in the distal right tibia. A healed but poorly aligned tibial fracture at the mid-shaft was also reported in a decapitated adolescent aged 14-17 years from a rural settlement at Barbraham Institute in Cambridgeshire (Dodwell 2007, 114).

In the primary study sample, fractures were identified in a total of 16 individuals (CPR 1.7%), 14 of which are new cases. Additionally, one case of either slipped capital femoral epiphysis or Perthes disease was newly identified, although not much can be inferred from an isolated case. The majority of fractures (68.8%) are in older children and adolescents, with 11 affected skeletons aged to 10.6 years and older. Two infants and two young children between the age of 1-2 years accounted for 12.5% of fractures each, and only one case was reported for children between 2.6 and 10.5 years (6.3%). Modern clinical data reported the highest rates of injury between the ages of 1-2 years, and 13-18 years, with the lowest annual rate in infancy (Ogden 2000, 43). This pattern is also apparent in Romano-British non-adults, with the exception of the two infant fractures. It may be tempting to infer that older children in Roman Britain were at greater risk of fractures due to the demands of labour, accidents or interpersonal violence. However, bone heals more rapidly the younger the individual. The lack of accurate techniques in fracture identification in infants and young children also means that fractures in younger age groups are often missed, although new methods are currently being developed (Verlinden and Lewis 2015).

It is difficult to assign the specific activity patterns that caused the various forms of skeletal trauma observed, although most of them affected the upper limb (62.5%), and can be attributed to a fall. Interestingly, all of the fracture cases reported from rural sites involve the upper limbs, mainly the clavicle. All of the clavicular fractures were sustained at the mid-shaft which is in concurrence with falls onto the arm or shoulder (Ogden 2000, 431). The

Monteggia lesion in skeleton 170 from Cannington would arise from a fall onto an outstretched hand. Chronic dislocation and malposition affected the mobility in the left arm of this individual. Perhaps, these fractures are a result of working with animals or heavy farming equipment, and accidents that may arise. Lower limb fractures were only observed in the major and minor urban samples, and would have required a considerable amount of force. The tibial diaphyseal fractures seen in two individuals from Dunstable and Cirencester resulted from either a direct blow to the element or a twisting force to the foot, and the femoral fracture in the 2-year old from Queenford Farm/Mill occurred in an age group where fractures are unusual. It may be that these injuries were sustained in accidents more likely in urban environments, perhaps in association with specific risks such as carts on the roads or unsafe timber constructions used in housing (Jones 2004).

Two infants from Winchester and Bradley Hill display possible indicators of birth trauma and complications during delivery. The fractured clavicle in the infant from Bradley Hill is most likely to have been sustained during delivery. The rib fracture in the Winchester infant is difficult to interpret and may also be the result of deliberate injury, inadequate care or prolonged illness.

7.11. CONGENITAL DISEASE

Identifying congenital disease in the Romano-British children may inform us on a range of subjects. It may serve as a measure of care for children in the community and family (Dettwyler 1991), or allow us to observe the treatment of ‘otherness’ in past populations. Although congenital defects can occur spontaneously, the rates of congenital diseases can also inform on maternal health and environmental pathogens (Alford et al. 1983; Queiβer-Luft et al. 2002; Watkins et al. 2003). Various forms of congenital disease in the archaeological record may go unnoticed, as not all conditions affect the skeleton itself. High infant mortality and the small size of the skeletal sample relative to the time span will also affect the visibility of disability in the Romano-British archaeological record (Southwell-Wright 2014). Barnes (1994, 5) stated that the identification of congenital defects in non-adult skeletons is further challenged due to the incomplete development of growing bone which may mask osseous or cartilaginous defects. It is likely that the actual rate of congenital disease in Romano-British children was higher than the rate of 0.9% recorded in the primary dataset, as modern clinical studies cite higher rates for major malformations at birth. In a modern study, Queiβer-Luft et al. (2002) included live and still births, as well as spontaneous and induced abortions over an eight year period and reported a rate of 6.9% of congenital defects. In a 1996-2000 study of single and multiple live births in Florida, Tang et al. (2006) found a rate of congenital disease of around 2.5% in single live births and 3.6% in multiple live births. Comparison of archaeological with modern data is restricted by the latter recording rates in either all births or live births only, whereas the archaeological sample consists only of excavated births, and is further affected by preservation and sampling (Roberts and Manchester 2010, 45).

There are examples of congenital diseases in the literature, such as the diagnosis, treatment and management of hydrocephalus in Antiquity (Lascaratos et al. 2004). Cases of congenital conditions in Romano-British non-adults are limited but include three individuals with probable and possible hydrocephalus (Duhig 1993; Reece 2000, 206; Roberts and Cox 2003, 115), talipes equinovarus in an adolescent male from Gloucester (Roberts et al. 2004), scaphocephaly in a 4-7-year old from Winchester (Clough and Boyle 2010, 372) and a 16-year old from Kingsdown Gallops in Berkshire (Mumford 2002), possible birth trauma in an adolescent at Kempston, Bedfordshire (Boylston and Roberts 2004, 343) and at Poundbury Camp, two possibly deaf children (deaf-mute) and Klippel-Feil syndrome (Molleson 1989; Lewis, pers. comm.). Some of these conditions would have been obvious physical and mental disabilities, and their presence in the Romano-British archaeological record implies that the communities these people lived in cared for affected children and adults. Several additional cases were found in the primary study sample including costal fusion, malformations of the spine, and a possible case of mild hydrocephalus. The majority of developmental defects recorded in the Romano-British sample are however spinal and rib deformities. Conditions such as the ones identified in the current study with rib and spinal involvement have not been previously reported, and in most of these cases it is difficult to differentiate between a congenital condition or a non-metric trait. Perhaps some of the spinal and rib anomalies may have gone unnoticed by the individuals, whereas others may have had more severe consequences such as restriction of the chest wall in fused ribs.

There are few references in the Classical literature to disabled children, and it is unclear to what extent Roman society distinguished between disability and illness (Laes 2008). The concept of disability is culturally determined, and our modern viewpoints may not be compatible with those of the past (Laes 2013, 125; Southwell-Wright 2014). Using literary sources as indicators of empathy and care, or for the maltreatment of disabled children have to be taken cautiously, as they are essentially case studies, often anecdotal in nature, and reflect the mindset of the upper classes in Rome (Southwell-Wright 2014). Laes (2013, 125) stated that a word for 'disability' in the modern sense did not exist in Antiquity. Moreover all babies were linked with mental incapacity, described as ugly and deformed. Soranus explained how the midwife must inspect the newborn to determine whether or not it is worth rearing, indicating a negative attitude towards children with physical disabilities (Laes 2008). Today's attitudes towards life in Antiquity are fraught with favouring brutality, where infanticide and exposure of disabled children are viewed the norm (Mays 1993; Laes 2011b; 2013, 129; Southwell-Wright 2014). When considering the infanticide hypothesis based on survival of the fittest, it is important to bear in mind that a number of congenital disabilities are not immediately apparent at birth, such as blindness and intellectual disabilities (Laes 2013, 131). The 5th century AD Greek historian *Herodotus* and *Pliny the Elder* in the 1st century AD remarked on deaf-mute children of the aristocratic orders who would go on to pursue specific careers such as painters or pantomimes (Laes 2011c). Two extremes are presented here, and may reflect adherence to concepts of Classical ideals of physical beauty, and changing attitudes with the rising popularity of Christian thought which regards every child as a gift of God (Laes 2011c). In the case of congenital disease in Romano-British children, the evidence may suggest parental and social compassion and empathy towards ill children, possibly as a product of Christian morals (Laes 2013, 137-138). This does not suggest that these children may have not experienced rejection or being viewed as a burden. Laes (2008; 2011b,c) stated that in Rome the mentally disabled were often concealed from public view and likened to animals. In the case of deafness and/or muteness, the common believe was that they were insane. A deformed child may have been viewed as an evil omen. Although these examples clearly show negative attitudes towards disability, they also unambiguously state that disabled children and adults lived within the community (Southwell-Wright 2014). Among the lower social orders especially, mental or physical disability may not have had as profound an impact on the affected individual and his or her family as opposed to higher ranking families. Deaf, mute or blind children may have still been able to perform profitable work (Leas 2011b), and certain types of disability, whether physical or mental may not always have been very obvious to people in the past.

7.12. ADOLESCENCE AND WORKING LIVES

The combined study sample showed a significantly higher number of 6.6-10.5-year olds dying in the major urban towns (X^2=15.68, p<0.001, d.f.=2), and probably reflects the higher number of individuals within these age groups represented in these settlements. A similar pattern was found when the primary data was examined, although merely a trend for higher mortality in the major urban sites was observed (X^2=6.45). In 14.6-17.0-year olds, the combined study sample also revealed a trend for higher mortality in the major as opposed to minor urban sites (X^2=4.57). This trend for lower mortality in minor urban sites as opposed to both major urban and rural sites was repeated in the primary study sample *(*X^2=6.50). Older children in Roman Britain may have migrated to major urban settlements, whether forced (possibly enslaved), or of their free will (to contribute to the family income) (Webster 2008). Towns were centres for commerce and trade, and tradesmen and artisans would have required apprentices and helping hands (MacMahon 2005). The lack of significant numbers of 10.6-14.5-year olds in major urban sites is difficult to explain, as they should also be expected to be on the move. It may be that the peak in the later age group is an artefact of the different ageing technique used in published reports that may result in older individuals being included in the 14.5-17.0 years category producing an artificial peak. In the primary study sample, higher mortality in the 10.6-14.5-year olds from major urban sites is apparent, however not significant which may be a product of small sample sizes and generally low mortality in this age group. Alternatively, children within this age group may have simply been exposed to fewer risk factors compared to those aged 6.6-10.5 and 14.6-17.0 years old, and were therefore less well represented in the major urban cemeteries.

Although there is limited documentary evidence, the existence of child (forced) labour is feasible given the temporal and social context. Iron Age societies may have also ‘employed’ children from a young age (Karl 2005), and kept or traded slaves (Arnold 1988, 188-189; Thompson 1993; Webster 2010, 55-56). Therefore the start to an early working life from the teens or pre-teens would have not been an entirely new sociocultural norm to Romano-British society. Webster (2010, 55) stated that it was common practice in many Roman provinces to provide slaves internally. Migration between rural and urban populations in Roman Britain has been suggested previously in the palaeopathological literature, in regional studies from Dorset and London (Redfern and Roberts 2005, 122; Gowland and Redfern 2010; Redfern et al. 2015). Children of the lower social classes would have also started apprenticeships, although the specific age is not clear (Bradley 1991, 112; Laes 2011a, 195). Bradley (1991, 108-110; 1994, 68) and Rawson (2003a, 121) remarked on household chores being the responsibility of freeborn children from about five years old, with apprenticeships starting at 12 or 13 years in Rome. In 10.6-14.5-year olds, significantly less enamel defects were recorded in the rural sample (7%), compared to the urban cemeteries at 17.3% and 18.2% (X^2=22.49, $p<0.001$, d.f.=2). If the working age fell into this group it may have posed additional nutritional, physical and psychological demands on these individuals that have already battled with stress in early childhood, and ultimately raised their mortality risk (Armelagos et al. 2009).

Children migrating for work in the Roman period may have been a similar phenomenon to the rural-urban migration patterns observed in the medieval period (Lewis 2002). The urban environment exposed these children to new pathogens, and coupled with the demands of physical labour, resulted in compromised health, and eventually raised mortality (Roberts and Cox 2003, 123). A trend in the distribution of cribra orbitalia in the 6.6-10.5 year age group was evident which shows a higher incidence of orbital lesions in rural compared to major urban children, albeit not significantly (rural TPR 66.7%, major urban TPR 20.8%; $X^2 = 4.53$). Although this is merely a trend, it is interesting nevertheless, as higher levels of cribra orbitalia were expected in the towns, based on the findings at Poundbury Camp (Lewis 2010). Higher levels of cribra orbitalia in the non-survivors from rural sites suggest an increase in stress within this age group, potentially indicative of the age at which children on rural sites were expected to perform heavy agricultural labour (Bradley 1991; Webster 2005, 165; Sigismund-Nielsen 2013, 289-290). If rural-urban migration occurred in this age group, perhaps the 'stronger' children would have been sent to the towns for work, whereas their slightly 'weaker' peers may have been left in the countryside, therefore elevating cribra orbitalia prevalence proportionately.

The vast majority of individuals living on rural sites would have earned their living with agricultural labour, although a minority may have found non-agricultural employment in extraction industries, small-scale manufacturing, construction or retail and distribution (Cleere 1982; Whittaker and Garnsey 1997; Esmonde Cleary 2004; McCarthy 2013, 7, 90). Especially as children grew older they would have taken on more responsibility for securing the family income, and become increasingly involved in the working life (McWilliam 2013, 276-277). Agricultural labour without the help of modern machinery is physically exceptionally strenuous, and peasants would have also worked and lived in close quarters with livestock, exposing them to diseases and an increased risk of accidents (McCarthy 2013, 43). Adequate nutrition and rest are paramount in keeping the detrimental effects of heavy physical labour at bay (McCarthy 2013, 2). During the later stages of Roman rule, the countryside would have also played in important role in manufacture and the provision of raw materials (Esmonde Cleary 2004). Perring (1991, 89) and Hall (2005, 141) stated that especially during the 4th century AD, there was a trend for larger scale industrial centres to be moved out of the towns and into the countryside, largely to avoid the ever-increasing taxation on industrial activity in urban settlements. This in turn may have led to some adolescents migrating into these rural areas for employment. Cannington in Somerset yielded the largest adolescent cohort from a rural site (n=14, 93.3% of rural 14.6-17.0-year olds), and is a cemetery believed to have served a community of rural settlements in the Romano-British west. Evidence for industrial activity such as metal-working has been found surrounding the settlement sites, and limestone and sandstone are present in abundance to be used as raw materials (Rahtz 2000, 31-38, 393). Its location close to the river Parrett and links to a nearby Roman road, coupled with good grazing pastures for animal herding and arable soils for farming would have made this area a prime spot for larger scale agricultural activity, and possibly even quarrying for the limestone and sandstone rock on an industrial scale (Rahtz 2000, 393). The two clavicular and one ulnar fracture at Cannington may be a result of having to work in close contact with traction animals such as cows or horses. There is no archaeological evidence for quarrying during the Roman period at Cannington, although quarrying took place during the medieval and post-medieval periods which may have obliterated any Roman workings (Rahtz 2000, 423; McCarthy 2013, 101). However, we do know that stone extraction on an industrial scale on quarry sites throughout Roman Britain would have been required to sustain the urban and military building trade (de la Bédoyère 1993, 87-95; Jones 2004; McCarthy 2013, 101). It may therefore be likely that quarrying took place at Cannington, which suggests an influx of low-grade workers (McCarthy 2013, 102).

More deaths of adolescents in major urban settlements may have been the product of environmental stresses specific to highly urbanised sites. Although Roman town planning tried to eradicate certain health and safety risks through features such as sewerage, the densely populated poor districts of these large towns, and close proximity of space for living and working would have still exposed their inhabitants to health risks (MacMahon 2005; Gowland and Garnsey 2010, 149; Lewis 2010). Not everyone had access to fresh water, and the crowded and narrow alleyways would have been polluted by waste. Bath houses and public toilets, although seemingly beneficial to hygiene and health, would not have been maintained to a standard that we deem as hygienic today (Roberts and Cox 2003, 123-130). Lastly, towns were constantly under construction, with some buildings unsafe, increasing the risk for accidents (Jones 2004; Hall 2005, 137). Indeed, four of the six (66.7%) fractures sustained by non-adults from major urban sites affected the upper and lower limbs which may have been sustained by falls. By 17 years, adolescents in towns would have had to contribute to their family's livelihood, whilst also experiencing an increasingly public life that exposed them to a greater risk of work-related accidents (Rawson 2003a, 121; Laes 2011a, 195).

Mortality in minor urban settlements was the lowest in the primary sample. This may have been simply because fewer adolescents were living there as a result of looking for work in major towns, or having to contribute to the running and survival of the family farm. Alternatively, minor urban sites may have provided a living environment that presented the best (as opposed to the worst) of both worlds: a settlement with urban amenities but rural in character. Rather than the peasant population, those living and working in minor urban towns may not have been affected by land taxation and debt, and heavy agricultural labour. A less densely populated and industrialised living environment would have also minimised some of the pathogen and stress exposure experienced in the major urban towns (Bonsall 2013b, 313). Interestingly, true prevalence rates of enamel hypoplasia are significantly higher in minor urban cemeteries in adolescents (23.8%), than both the rural (4.2%) and major urban (7.8%) samples (X^2=46.31, p<0.001, d.f.=2). The high rates of enamel hypoplasia in the minor urban sample may be a product of migration, and use of the cemeteries by rural as well as minor urban communities (Goodman 2007, 76-78; Laurence et al. 2011, 288; Redfern and Gowland 2012, 119). This observation somewhat supports Bonsall's (2013b, 312-313) conclusions on lives in minor urban towns, which were characterised by an agrarian existence. It is difficult to pinpoint the specific factors that have led to fluctuating mortality in adolescents across the diverse Romano-British settlement types, but it is likely that several stresses specific to living in towns or in the countryside acted on their physical wellbeing.

7.13. ROMANO-BRITISH CHILDHOOD HEALTH IN CONTEXT

7.13.1. Parallels with Late Iron Age Dorset

Osteological data from the Iron Age (800 BC to the Roman conquest in AD 43) is notoriously difficult to obtain because of the great variety of burial practices during this period (see Tracey 2013). Only few sites have produced a limited number of non-adult skeletons, and an even smaller fraction of these have been studied and published.

Overall, stress markers such as enamel hypoplasia, new bone formation and cribra orbitalia were reported less frequently in the non-adults from Late Iron Age Dorset, compared to the Romano-British sample. These trends may signify the lifestyle changes experienced by children from the Iron Age through to the Roman period, with the latter having a more negative effect on health, perhaps as a result of cultural buffering (Redfern and DeWitte 2011a,b). Early childhood stress, infection, and compromised nutritional status were more prominent in the Roman sample, indicating that it was not just the urban but also the rural settlements that showed a decline in health from the Iron Age to the later Roman period. The Iron Age would have been generally characterised by a low infection and disease rate, with a relatively varied and satisfactory diet based on agricultural intensification and use of wild resources (Roberts and Cox 2003, 91-100). As of yet, we are still unclear whether status of different social groups impacted on health in the Iron Age (Roberts and Cox 2003, 103). However, Jay and Richards (2006) attested that isotopic signatures in 62 adult individuals buried in graves suggestive of either high or low status at Wetwang Slack in East Yorkshire varied very little. Animal protein would have been widely available, regardless of status. The differences observed in child health between both periods may be taken as further evidence for the social changes experienced by the native population following the Roman conquest, with higher status urban dwellings on one end of the spectrum, and an impoverished and exploited peasantry on the other. The crude prevalence rate for rickets was highest in the children aged 0-3 years from Iron Age Dorset at 11.1%. Sample size has to be considered here, as only one child out of a total of nine was affected (Redfern et al. 2012), whereas the Roman sample consisted of a minimum of 90 individuals per urban or rural group.

The crude prevalence of caries in 3-12-year olds from Iron Age Dorset at 16.7% is higher than the rate observed for children of this age group in rural Romano-British settlements (none reported), and similar to the one seen in children from major urban settlements (CPR 17.4%). Perhaps, this distribution is a remnant of the more restrictive diet consumed in rural Roman Britain, and may signify a more widespread consumption of fruits, honey, syrups and finely milled flour in Iron Age society. With reference to Jay and Richards' (2006) study, only little variation was observed in animal protein intake between social groups. Perhaps, a similar level of consistency in plant foods was also apparent, and the same foods may have been available to both high- and low-status groups, although their preparation may have differed. If this was indeed the case in Iron Age Britain, the increasing social stratification seen in the Roman period, accompanied by its impact on diet may have led to differences in oral infection between both time periods. This in turn may indicate worsening conditions for food availability and diversity with Roman rule. However, this interpretation is again constrained by sample size as only six Iron Age children were available for analysis.

7.13.2. Children in Roman Britain and post-medieval London

When interpreting the patterns of ill-health observed, it is important to bear in mind that the cemetery at Christ Church in Spitalfields was used by the upper to middle class members of the local population, and some families may have sent their children to the countryside to be breastfed by wet nurses (Fildes 1986, 152-153; Lewis 2002c). Therefore some of the children buried at Christ Church may not have been exposed to the urban environment during early childhood which may have impacted on their skeletal health (see section 7.3.1).

Early childhood stress affected urban children to a similar degree in both time periods, and this may perhaps indicate parallels in the urban environment regarding crowding, pollution, and exposure to pathogens and disease. It is not surprising that proportionately more children were diagnosed with rickets in London during the Industrial revolution, as vitamin D deficiency was so widespread in the mining and industrial towns of England during this period that it was referred to as the 'English disease' (Gibbs 1994). The rates of pathology seen in the rural Romano-British children at greater frequencies compared to their urban peers, such as cribra orbitalia and metabolic disease (no data for scurvy alone was available for the Christ Church, Spitalfields non-adults) are considerably below those of children in post-medieval London. This may indicate that, although nutritional status was compromised in rural children in Roman Britain, their diet was still more adequate than the foods available to children during the Industrial revolution in London. They may have suffered comparatively less from parasitic infections, high pathogen load and systemic stress compared to children of this later period (Pinhasi et al. 2006; Ogden et al. 2007).

Throughout all age groups, cribra orbitalia was most frequent in the children from post-medieval London. No cases from Spitalfields have been reported in the 14.6-17.0 year age group, which is impacted by sample size (N=6, with observable orbits n=2) (Lewis 2002c). Rural Romano-British children had the same rate of cribrotic lesions in 6.6-10.5-year olds (TPR 66.7%) than children from Christ Church, Spitalfields, and a very similar rate in 0.6-2.5-year olds at TPR 50.0% versus TPR 53.7%. Pathogen load and nutritional stress may have been similar in both groups and reflect weaning and early childhood feeding practices aged 0.6-2.5 years, and possibly the impact of commencing physical labour by the time the children reach 10.5 years. Enamel hypoplasia was reported at higher rates in the Spitalfields children aged 0.6-2.5 years, and 10.6-14.5 years, compared to the Roman sample. Interestingly, in 6.6-10.5-year olds the highest rate was reported in the rural Romano-British sample. This result may indicate a greater mortality risk for children in the Romano-British countryside who experienced elevated morbidity in early childhood. This finding complements the high rates of cribra orbitalia in rural children and those from Spitalfields in the same age group. Similarly, in 6.6-10.5-year olds, sub-periosteal new bone formation also occurred most frequently in the rural Romano-British children. Apart from 10.6-14.5-year olds, prevalence rates were consistently higher in the Romano-British cohort. Lewis (2002c) solely included individuals with tibiae, whereas the Romano-British sample comprises of non-adults with postcranial bones, and comparison between the two studies is therefore tentative.

In 0.6-2.5-year olds, the frequency of metabolic disease in the rural Romano-British cohort is only marginally less than in the post-medieval sample, at CPR 20.5% as opposed to CPR 21.9%. From 2.6 up until 14.5 years, metabolic disease was most prevalent in rural Romano-British children, although vitamin C/D deficiencies were declining with increasing age in children of the Roman and post-medieval period. These trends indicate even greater nutritional stress in children aged 2.6-14.5 years from rural Roman Britain, compared to post-medieval London. We may assume that vitamin D deficiency predominated in the children from Spitalfields (Lewis 2002b, 86), whereas scurvy was more prominent in the rural children from the Roman period. The aetiology behind the metabolic disturbances in children from Industrial London and rural Roman Britain are therefore very different, and reflect the specific sociocultural, economic and physical environments these children were exposed to. The densely populated urban environment and industrialisation of post-medieval London prompted high rates of rickets in the children (Mays et al. 2006). Expressions of high rates of the disease would have been buffered against by the largely agricultural lifestyles of Romano-British children in the rural environment (Pettifor and Daniels 1997).

Overall, comparison of stress markers, nutritional disease and metabolic disturbances between the Romano-British and post-medieval sample has shown that patterns in ill-health are most similar between the rural Roman cohort and Industrial London. Especially between the ages of 6.6-10.5 years, rural Romano-British children experienced increased morbidity, even surpassing some of the rates reported from Spitalfields. This is a surprising finding and challenges some of the preconceptions regarding urban and especially rural life in Roman Britain. These observations also add weight to the hypothesis that growing up in the countryside may have been more challenging than in the towns. If we take into account that life in the countryside may have been dictated by agricultural labour and a restricted diet (see section 7.14), similarities with the lifeways of post-medieval children transpire, mainly regarding physical labour and little dietary variability (Roberts and Cox 2003, 294, 307-308).

7.14. PATHOLOGIES OF POWER – IS THERE EVIDENCE FOR RURAL EXPLOITATION?

As discussed in Webster (2005), Mattingly (2006; 2010) and McCarthy (2013), the rural population may have formed the backbone of an exploitative Imperial system. Both Pitts and Griffin (2012) and Redfern and colleagues (2015) have reported on compromised health in rural populations from Dorset, and more widely central and southern England. The primary study sample has revealed interesting and unexpected differences in morbidity and mortality between urban and rural Romano-British non-adults. Children from major urban sites displayed higher frequencies of new bone formation and tuberculosis, and significantly elevated rates of enamel hypoplasia and caries. In contrast, there were trends for elevated rates of cribra orbitalia, porotic hyperostosis, rickets and endocranial lesions in the rural children, with vitamin C deficiency significantly elevated in children from the countryside. Overall, these patterns suggest differences in weaning practices and childhood diet between town and country. Trauma that may be linked with intense physical activity was found on rural sites, including a 16-year old female at Cannington who showed degenerative lesions in the spine (skeleton 277) (Brothwell et al. 2000, 203).

If we combine mortality in those born prematurely or small-for-gestational age with full-term births to evaluate all perinatal deaths in the combined study sample, mortality in the rural sites is significantly higher than elsewhere in Roman Britain with 30.0% (n=95), compared to 16.1% (n=143) in major urban sites and 19.1% (n=84) in minor urban sites (X^2=28.19, p<0.001, d.f.=2). The greater level of perinatal mortality seen in the combined sample suggests higher levels of maternal stress compared to their urban counterparts (Dejin-Karlsson and Ostergren; Norton 2005; Steer 2005). This is a very tempting observation, but we have to keep in mind the limitations of interpreting infant mortality in Roman Britain (see section 7.2). However, the fact that a dedicated ritual was practised for those who died within the first year of life, particularly on rural sites in the primary study sample, might itself be an indicator for high infant mortality. If we accept that perinatal mortality in rural environments was higher than in the towns, some interesting conclusion can be drawn. What we are observing with the increased rate of perinatal deaths in rural sites may be the effects of hard physical labour on women who were possibly bonded tenants (*coloni*) (Whittaker and Garnsey 1997, 284; Clarke 1998, 140-141; Millett 2005, 66-67; Pitts 2008; Mattingly 2010, 140; McCarthy 2013, 41). McCarthy (2013, 33-40) estimated that over 90% of Roman Britons lived on rural sites. Therefore proportionately more babies would have been born and died in rural contexts. More perinates and infants in the rural cemeteries are not only reflecting greater population numbers but potentially also proportionately more births, shorter inter-birth intervals, and higher fertility (Scott and Duncan 1999a,b; 2000; Larsen 1997, 339). In developing countries today, high fertility is linked with poverty (Birdsall and Griffin 1988). The result may indicate that the rural population in Roman Britain was impoverished relative to those living in urban settlements.

Moreover, research on other past populations during times of rapid economic change and modernisation have demonstrated a negative impact on health (Huck 1995; Komlos 1998; Lewis and Gowland 2007). The Roman conquest brought about a swift population increase and extensive reorganisation of the rural landscape and farming techniques, which may have compromised health in rural contexts more so than in urban environments (van der Veen et al. 2008; McCarthy 2013, 58-59; Breeze 2014). Towards the end of the Roman rule, changes in landownership and increasing agricultural production may have had a similar impact (Jones 1982; Pearce 1982; Faith 1997, 17-18; Whittaker and Garnsey 1997). Taxation changed from money to kind during the 4th century AD, and grain would have been the predominant means of taxing the province. The rural population was under increasing strain to pay for both the urban population and army (Jones 1996, 208-213). Higham (1982, 105-106) estimated that the average Romano-British farmer would have lost between 1/2-2/3 of his net yields to provide for the non-producing population, which would have undoubtedly impacted on wellbeing in the farming communities.

Life in Roman Britain may have been shaped by ecological constraints to a certain extent but both political and economic agendas would have affected the health and wellbeing of its inhabitants (Goodman et al. 1992; 1995; Bhalotra and Heady 2003; Larsen and Walker 2010, 387; Klaus 2012). We also have to bear in mind that although Roman Britain was governed by a central political power, it still consisted of groups that differed either by region and class or according to more complex social barriers such as religion, ethnicity or language, some of which may have borne resemblance to Late Pre-Roman Iron Age society (James 2001; Taylor 2001b; Eckardt 2010a; Maru and Farmer 2012; Millett 1990, 29-59; 2014). Children in rural Roman Britain suffered more from nutritional deficiencies and endocranial lesions than those from large towns, and it has been suggested previously that the rural population may have been exposed to high levels of stress and physical labour (Griffin and Pitts 2012; Redfern et al. 2015). Dietary restriction is a direct result of biased food allocation, where a more varied diet is accessible to higher status individuals (Crandall 2014; Halcrow et al. 2014). What we are observing in the rural children is likely to be food poverty, a phenomenon that can be observed world-wide across both developing and developed countries today. What is also of interest is the absence of a statistical difference in the distribution of rickets between urban and rural children, although it was anticipated that rickets was less likely in children in the countryside. Based on the spectrum of calcium and vitamin D deficiency that rickets can occur on, we may suggest that rickets in urban children developed due to vitamin D deficiency as a result of inadequate hours in sunlight, whereas rural children may have developed the condition due to lack of dietary calcium and intestinal malabsorption of the element, probably exacerbated by diarrhoeal disease and high phytate intake of a cereal-based diet (Pettifor and Daniels 1997). This is not to say that children in rural Roman Britain suffered from pathological hunger or starvation, but suggesting that their diet simply did not cover their physiological demands. Physical labour elevates energy expenditure and therefore nutrient intake (Bouchard et al. 1983). One would assume that food, especially fresh fruits and vegetables, and animal produce would be more readily available in the countryside. If however, the rural population is largely concerned with providing for the non-producing urban population, army, and rural elite, resource and food allocation will become skewed and favour the higher status groups (Goodman et al. 1992; 1995). Isotopic and zooarchaeological analyses have validated status differences in the consumption of meat, fish and plant foods

(King 1984; 1999; 2001; Cool 2006; van der Veen et al. 2007; 2008; van der Veen 2008; Alcock 2010; Müldner 2013). In part, this is also confirmed by significantly higher rates of caries in urban children which suggest fine milling of grains, and higher fructose and glucose content of the urban diet. It may seem contradictory that enamel hypoplasia occurred at significantly higher rates in the urban children, demonstrating that early childhood stress was elevated in the towns. However, what this stress marker most importantly shows, is that children in the urban environment experienced physiological stress episodes that were survivable. Fewer instances of enamel hypoplasia in the rural children therefore do not simply imply lower levels of early childhood stress, but a lower number of children who survived the influence of these stressors to exhibit enamel hypoplasia (Goodman et al. 1995). Klaus and Tam (2009) found that the instance of enamel hypoplasia declined in Peruvian colonial populations when other pathologies were on the rise, as there was a shift from survivable health insults in early childhood to elevated mortality. This reasoning is in part confirmed by a statistical trend for lower mortality in children aged 1-4 years in the major urban towns (see section 7.6). This in turn ties in with proportionately more babies dying in rural sites, which by itself is a witness to an impoverished part of society: higher infant mortality is a product of higher fertility and shorter inter-birth intervals which in turn are linked with poverty in contemporary ethnographic and evolutionary studies (Birdsall and Griffin 1988; Scott and Duncan 1999a,b; 2000). However, as discussed in section 7.2, any inferences drawn from the interpretation of infant mortality come with the caveat of differential burial rites. Age-based patterns in the distribution of enamel hypoplasia yield more straight-forward evidence for stress in the rural population: in 6.6-10.5-year olds, true prevalence rates of enamel hypoplasia rose to 14.3% from 0.8% in 2.6-6.5 year olds, and are marginally higher than in the major urban sample at 13.6%. This demonstrates that early childhood stress was indeed present in the rural children, its effect on mortality is however different to the urban children. The sharp increase in enamel defects in those that died between 6.6-10.5 years old may be an indication of specific demands placed on rural children within this age group, possibly the need to start working physically in agricultural or domestic settings. Those that lived through early childhood stress severe enough to manifest in enamel disruptions may have then experienced elevated mortality compared to their peers who were ‘stress-free’ in early childhood.

We therefore observe several indicators for social inequality in Romano-British non-adult populations from urban and rural backgrounds (Martin et al. 1984; Goodman et al. 1995; Maru and Farmer 2012). Rather than just focussing on the aetiologies behind the urban-rural dichotomy in disease and mortality patterns, it may be of interest to seek a wider picture of living and dying in rural Roman Britain (Goodman et al. 1995). Based on the patterns of ages-at-death, and the incidence of scurvy, rickets, anaemia, endocranial lesions and enamel hypoplasia in Romano-British children, we may search for analogies in modern societies.

Farmer's (2003) "Pathologies of Power" provides an important framework on how poverty and marginalisation affect the health status of the individual and community at large. Structural violence as an invisible or subtle form of violence is often established in long-standing social systems based on inequality, where one social group oppresses another and prevents it from flourishing economically, biologically and socially (Farmer 2003, 219-220; Bourgois 2009, 17-19; Klaus 2012). Examples in modern day societies validate that political, civil and legal matters are deemed more important than the right to food, sound health and education (Farmer 2008). The poor remain persistently poor due to a higher disease burden which causes low productivity which in turn leads to low income as capital is accumulated at a lower rate than it is depreciated, a phenomenon referred to as 'poverty traps' (Ngonghala et al. 2014). Modern studies on structural violence and poverty traps focus on household income, tuberculosis, HIV and childhood mortality (Farmer 2003; 2008; Rylko-Bauer et al. 2009; Ngonghala et al. 2014), but Klaus (2012) has demonstrated how a consideration of these processes can aid in interpreting patterns in skeletal health within a historical context of hierarchical societies that goes beyond the mere gross visibility of violence as fractures and other traumatic injuries. Additionally, in 2014, the International Journal of Palaeopathology devoted an entire volume to advances in the palaeopathology of scurvy, with some papers linking vitamin C deficiency with social inequality and structural violence. Proximity and relationships with regional political centres also play a crucial role in health (Goodman et al. 1995). Children in hinterland communities are more prone to scurvy as a result of adverse preference in resource distribution (Crandall 2014). The segment of society from which resources are extracted ultimately becomes the most vulnerable and deprived (Goodman et al. 1992; 1995). Furthermore population aggregation in the form of expanding urban centres as seen in the Roman period has an additional impact on food quality: food security and redistribution is controlled by an elite minority who strives for both political and economic gain (Goodman et al. 1995; Faith 1997, 4-5; Whittaker and Garnsey 1997; Crandall 2014). There is no doubt about the social hierarchy that accompanied the Roman Imperial system but the extent of exploitation of the peasantry remains unclear, especially in Roman Britain. Perhaps these sometimes very subtle inequalities in child health are a witness to exploitation, oppressive working and living conditions, or forced labour of the rural population. Living and working under exploitative conditions leaves psychological and physical marks, some of which we have observed osteologically.

Written and iconographic evidence for slavery in Roman Britain is scarce, so we cannot assume that the entire rural population was enslaved (Tomlin 2003; Webster 2005; 2008; 2010; McCarthy 2013, 8). However, we can reasonably assume that land was mainly distributed between *villa* estates and landowners who employed agricultural labourers or rented farmland to bonded tenants, somewhat reminiscent of later manorialism (de la Bédoyère 1993; Jones 1996; Millett 2005, 66-67). Faith (1997, 4-5), in her discussion of the English peasantry and lordship during the Anglo-Saxon period, stated that political power began to shift from the urban centres to the countryside as early as during the 4th century AD, and taxes and rent paid in surplus and goods were increasingly benefitting the rural elite as opposed to the Roman state. Taxes would have to be paid in produce and resources which would then profit the landlords and managerial *conductores*, traders and officials (Whittaker and Garnsey 1997; Faith 1997, 3-4; McCarthy 2013, 6-8). Patronage systems may be seen from the 4th and 5th centuries AD, in some respects similar to feudalism in Medieval Europe (Whittaker and Garnsey 1997, 309-311). The cereal agriculture of Roman Britain may have been extensified in the 4th century with increasing areas of land being cultivated. Additionally, there is evidence for the imposition of field systems to further aid intensification (Esmonde Cleary 2004). In the 4th and 5th centuries AD, the Romano-British peasantry may have experienced additional pressures for raising surplus and paying taxes and rent due to economic shifts and events on the continent (Jones 1982, 2004; Esmonde Cleary 2004). Famine in the Rhineland may have required Britain to deliver produce to the cities (Fulford 2004, 316). Britain had also become one of the main exporters of crops to the large Rhine army, which increased demand for produce whilst the manpower remained the same (van Gerven et al. 1981; Jones 1996, 215; Whittaker and Garnsey 1997, 285). Ultimately this placed a greater strain on the rural population, as the part of society from which resources are extracted is most affected by political instability and food shortages. Since we are concerned with the later phases of the Roman period, we also have to consider the church as a powerful new landowner who would have impacted on land distribution, tenancy and taxation throughout the Roman Empire but also Roman Britain (Jones 1982; Faith 1997, 16-18; Whittaker and Garnsey 1997, 301; Esmonde Cleary 2004). The earliest British monastic sites may have been founded on *villa* estates which may have also come with a tied workforce, or at least required tenants and labourers to ensure farming and livestock management (Dark 2010, 105-116). Additionally, the earliest church founders themselves would have originated from landowning families (Pearce 1982; Faith 1997, 17-18).

Regardless of the precise sociopolitical or religious processes, what stands out is that although the children of the rural population may have been exploited, they were not starved or enslaved according to our modern conceptions of oppression and child labour (Edmonds and Pavcnik 2005). Had this part of society experienced extremes in nutritional and environmental stress and disease, they would not have lived to exhibit skeletal lesions. We therefore have to consider more moderate chronic and long term factors that led to this depression in rural health status, and rather than slavery, a system of land tenancy or manorialism may be more pertinent (de la Bédoyère 1993, 86-92). Overall better nutritional status in the small towns and major urban centres further supports the premise of social injustice and preferential resource allocation to higher status and more 'Romanised' settlements (Whittaker and Garnsey 1997, 284; Müldner 2013; Redfern et al. 2015).

The implications of this theory for our current knowledge of everyday lived realities in Roman Britain are important. To date, most of what we know about Roman Britain is derived from settlement archaeology focussing on the towns and *villae*. Alternatively, ideas are taken from the Roman literature written by elite males of the Republican era. As a result, the vast majority of Roman Britons living in the countryside have remained archaeologically silent, even more so the women and children, similar to the "voiceless poor" in developing and developed countries today (Farmer 2008). This thesis is not only suggesting a certain kind of lifestyle for the rural population, but also urges us to reconsider our ideas of living and working in Roman Britain, and how we source our understanding of daily life. Moreover, by suggesting that the rural population displayed pathologies of power, further validation is desired and more skeletal data, both adult and non-adult, from rural sites needs to be recorded.

With reference to Poundbury Camp, the discussion has also revealed that health in urban settlements was not uniform. Some of the levels of pathology found in rural children bear resemblance to those described for Poundbury Camp by Lewis (2010). We have to consider the possibility of rural individuals who have found their way into this urban burial assemblage, either by way of migration or due to settling in the *suburbia* and hinterland. Roman Dorset may have either been a poorer locale of lower status, or alternatively a hub for early Christian followers who believed in ascetic practices for women and children. Possibly, both these factors may have come into play. The vast pastures of the Dorset countryside would have lent themselves for division between rich and powerful landowners, whereas *Durnovaria* also displays evidence for a following of the early church (Sparey-Green 1993, 135-139; Woodward 1993, 236-237). Pearce (1982) and Faith (1997, 18) have suggested that Dorset may have been inhabited by an early Christian Romano-British aristocracy that was in charge of land management, and enabled the early Anglo-Saxon church to take hold in later periods. It is therefore likely that all these factors contributed to the high levels of pathology seen at Poundbury Camp, and to some extent skeletal populations across Roman Dorset. The sociocultural and political tiers rendering the peasantry poor, and landowners and early church founders rich, may have been at work across Roman Britain, but potentially at a more pressing scale in Roman Dorchester and its surroundings area.

CHAPTER 8. CONCLUSIONS AND DIRECTIONS FOR FUTURE WORK

8.1. CONCLUSIONS

This project set out to investigate child health in Roman Britain under the following aims:

- To provide a national overview of non-adult palaeopathology across Romano-British sites in England, and to demonstrate the value of this approach in elaborating on lifeways in Roman Britain without over-reliance on the Classical literature.

- To acquire new insights into everyday lived realities of children in both urban and rural settlements and contextualise the levels of ill-health observed at Poundbury Camp in relation to other Romano-British settlement contexts.

The main conclusions of this research are that there are/is:

- Statistically significant differences in mortality and morbidity between major urban, minor urban and rural Romano-British children.
- Distinct burial rites for newborns and infants that prevent us from interpreting neonatal and post-neonatal mortality. However, considering their palaeopathology is a helpful avenue for interpreting health and wellbeing in early life.
- Patterns in the health and ages-at-death of urban and rural children that suggest a young working age, and possibly migration between town and country in search for work.
- Three new cases of probable childhood tuberculosis not previously reported.
- At least one new case of probable non-adult thalassaemia not previously reported.

Moreover:

- The rural population suffered more from nutritional deficiencies than those living in the towns, potentially as a result of exploitation of the peasantry.
- Child health in towns indicates more ‘Romanised’ lifeways in urban settlements.
- Child health in Roman Britain, more so in rural sites, shows similarities to morbidity patterns seen in post-medieval children.
- There is an increase in childhood ill-health and stress from the Late Iron Age to the Roman period.

- The children at Poundbury Camp exhibit patterns of ill-health that are unusual compared to the remainder of sites from Roman Britain.
- Treatment of Romano-British children in death did not differ significantly depending on their palaeopathology.

This thesis has contributed new insights into what it was like to grow up in Roman Britain, and the sociocultural processes that shaped health and wellbeing in rural and urban environments. The overview that the combined study sample has provided for non-adult mortality and morbidity gave first insights into child health in Roman Britain, indicating a compromised health status in the major urban towns. However, this pattern was not reflected in the more in-depth analyses undertaken using the primary study sample. This raises a number of issues regarding the use of (un)published data. Firstly, the need for standardised recording of non-adult skeletons from Romano-British collections, and also the need for re-analysis of these collections. The initial patterns seen in the crude prevalence rates of stress and disease in the combined study sample also provide much needed motivation for historians and Roman archaeologists alike to include non-adult palaeopathology in the repertoire of exploratory tools for everyday realities in Roman Britain.

It is very frustrating that the interpretative value of neonatal and infant mortality is limited by differential burial rites, such as intramural burial or exclusion from the formal cemetery. Mortality patterns within these groups yield a wealth of information on exogenous and endogenous factors of the living environment, as well as helping us decipher maternal health (Branca 2015). However, by accepting that a distinct funerary ritual did exist for those dying soon after birth, we can still make valuable inferences on sociocultural variables between settlement types. Apart from infants and newborns, treatment in death was generally not distinctly different for any one group, whether urban or rural, or according to illnesses children may have experienced whilst alive.

Surprisingly, long bone growth between modern and Romano-British children did not differ in a statistically measureable manner, but we have to acknowledge the limitations that a comparison of measurement averages, and more importantly cross-sectional and longitudinal data, encompasses. Comparison with femoral diaphyseal lengths reported from post-medieval London allowed an evaluation of cross-sectional Romano-British data in the context of a well-documented historical period and in an environment where health insults to children were rife. Significantly shorter femora in the Roman period may be a product of the interaction of both environmental and genetic factors, which ultimately impacted on growth more critically than in post-medieval London. Given the higher rates of nutritional deficiencies and stress experienced at Spitalfields, a genetic component seems even more likely. Yet, within the Romano-British sample itself, no differences were found in femoral growth between children from rural or urban sites, which may suggest that each settlement type posed health stresses, albeit dissimilar ones.

Evidence for weaning patterns in Roman Britain could be traced osteologically by observing a slight increase in mortality in children between 2.6-6.5 years old and an accumulation of nutritional deficiencies in those under the age of 2.5 years. Supplementary foods may have differed between urban and rural settlements, perhaps due to status and locale, but most likely as a result of different sociocultural backgrounds. Mothers and primary care-givers in the major urban towns may have subjected their children to more 'Romanised' supplementary foods and weaning practices as outlined in the *Gynaecology*. Different weaning foods may have been given to children on rural sites, and the onset of transitional feeding at around six months old may have also deviated.

Differences in diet were not only observed in weanlings but also older children by observing oral health and nutritional deficiencies. Caries in early childhood was more frequently seen in the major urban cohort and gives further information on the weaning foods consumed by these children, i.e. soft and carbohydrate-rich foods and honey which were essentially higher status items, and sharing of utensils and food between mother and child. Less glucose and fructose may have been consumed by rural children, potentially because these foodstuffs were not available, and the diet may have been coarser overall. These differences in dental health persist into later childhood, giving first insights into the foods consumed in childhood past the weaning age. Unavailability of certain foods within the rural community is a hypothesis reinforced by higher levels of scurvy in rural children, and elevated rates of cribra orbitalia in certain age groups. Fresh fruit and vegetables should be plentiful in the countryside, and their lack in the diet of those growing up outside of the towns points to more widespread issues in food allocation and availability in Roman Britain. Recent research has argued for similar conclusions on a poor and stressed rural society in Roman Britain, and Rome itself (Pitts and Griffin 2012; Redfern et al. 2015; Hin, no date). Contrary to long held beliefs about adverse living conditions in Romano-British towns, these results urge us to reconsider our current understanding of living and dying in the towns and the countryside. Rural settlements have been disregarded previously, but the result presented here urge us to consider the health and lifestyle implications that landownership and bonded tenancy had on the majority of the population in late Roman Britain.

Survivable early childhood stress, measured as enamel hypoplasia, was more pertinent in the urban settlements and occurred at lower rates in rural children. However, the absence of enamel defects does not attest that rural childhood was stress-free. In contrast, rural individuals may have experienced a shift from survivable early childhood health insults to higher mortality, which either points towards greater stress, or generally more compromised health in these children compared to their urban peers. Overall, the distribution of enamel hypoplasia confirm that growing up in Romano-British urban dwellings was a stressful experience, regardless of whether external stressors were more pressing or moderate in rural environments.

The results pinpoint similarities in the risk for infection across urban and rural settlements. However, how we record and interpret infectious disease in non-adults remains disputed, and the distribution of periosteal new bone formation across the sites and age groups has confirmed the ambiguous and non-specific aetiology of this stress marker. The presence of tuberculosis and possible respiratory infections in Romano-British non-adults from both major urban and minor urban settlements clearly demonstrates that ongoing transmission and infection with the disease was prevalent in the towns of later Roman Britain. These findings also highlight the need for re-assessment of the adult cohort in these sites, as it is likely that there are more instances of tuberculosis in the adult population than previously recorded. Respiratory infections were present in individuals of all settlement contexts, albeit more frequent in children from major urban sites which supports the hypothesis of overcrowding and poor sanitation in towns.

Similar to the medieval period, older children and adolescents may have migrated from rural settlements to the towns. Although migration in the Roman period has been discussed previously, the main focus has been on isotopic studies of 'foreigners', rather than rural-urban movement of the native population. Whether this migration was forced or voluntary remains debated, but we have to accept that slavery was common in Roman and Iron Age society, and would have affected men, women and children alike. However, the presence of slaves in Roman Britain is still in question. It may therefore be likely that these children were low-grade workers rather than slaves, and sought employment in the towns. Given the new insight into living conditions and possible exploitation of the peasantry in the countryside, moving to the towns may have seemed like an attractive option to young Roman Britons. Evidence for thalassaemia as an osteological marker for migration from warmer climes to *Britannia* was not as strong as expected, based on the findings at Poundbury Camp (Lewis 2012). However, the absence of a number of probable cases of the genetic anaemia does not negate the presence of immigrants and second generation migrants in settlements other than *Durnovaria*.

In future work, more isotopic analysis of both adult and child skeletons is desirable to address migration to Roman Britain as well as within the province itself.

Comparison of childhood health in Roman Britain with Late Iron Age and post-medieval samples can help in contextualising some of the findings, especially those relating to health in rural Romano-British settlements. Childhood diet may have been more varied during the Iron Age and became more restricted, particularly in rural settlements towards the end of the Roman rule. Additionally, there was an overall increase in biological and nutritional stress across all site types from the Iron Age compared to the late Roman period (unfortunately it is not possible to comment on the interim period, as the Roman samples mostly date to the 3rd-4th century AD and later). These health shifts may be the result of social and political changes experienced by the population between both time periods. It has been established in this study that the rural children were affected by nutritional deficiencies and infections to a greater extent than those growing up in urban environments. Appraisal of the poor health in the rural settlements with patterns of ill-health reported from Christ Church, Spitalfields allows us to better grasp the extent of pathology recorded in rural settlements. Romano-British children exhibited lower rates of pathology overall compared to those from post-medieval London. The pathological signatures of rural children, and especially those aged 6.6-10.5 years, is most similar to the distribution observed at Spitalfields, which points towards similar levels of labour, exploitation and poor diet.

The current study also aids in contextualising the high levels of disease reported from the Poundbury Camp cemetery of Roman Dorchester by Lewis (2010, 2011, 2012). This cemetery holds the highest number of cases of childhood tuberculosis with seven non-adults compared to three new cases found in the current study in the cemeteries of major urban Colchester and minor urban Ashton. Similarly, three non-adult individuals at Poundbury Camp show evidence for thalassaemia, whereas only one additional probable case has been identified in the current study. Some of the rates of metabolic disease and cribra orbitalia at Poundbury Camp are more similar to those seen in other rural Romano-British sites, and may perhaps indicate a high proportion of peasants included in this cemetery. Overall, in terms of non-adult palaeopathology, the cemetery at Poundbury Camp remains unique. It displays very ‘urban’ pathologies such as the high incidence of childhood tuberculosis, and the children with thalassaemia indicate that this must have been an attractive town for migrants from the Mediterranean. Yet, evidence for under- or malnutrition was also present, at similar levels to those reported in children from rural settlements.

Lastly, no significant patterns in the palaeopathology of children and how they were buried were found. The absence of a relationship is interesting in itself. Health or disease may not have warranted differential treatment in death. Ill children may therefore not have been viewed as substantially different within their respective communities. It is most likely that these observations are a result of standardised Romano-British inhumation practice which may have dictated similar treatment in death, regardless of illness experienced in life. Again, the inhumation cemetery at Poundbury Camp is unique in comparison. Here, patterns of ill-health and trauma in the children differ according to burial alignment which has been interpreted as a reflection of their cultural affiliations as pagan or possibly 'Christian'/'Romanised'.

8.2. FUTURE WORK AND RECOMMENDATIONS

It is desirable to expand the palaeopathological record in future work. Re-analysis of adult remains, especially from rural contexts would be of interest. Similarly, the retrieval of more non-adult skeletons from rural sites, and especially sites of both an urban and a rural nature in the north of England could add substantially to our current body of understanding.

Awareness of the chronology of very 'late' Roman burials and new radiocarbon dates will influence our understanding of life and death during the late Roman/early Medieval transition, as well as challenging late Romano-British skeletal collections (Gerrard 2015). Contextualising Romano-British childhood health by using Anglo-Saxon and Iron Age data will also allow us to gain a better grasp of the social and political forces and hierarchies that will have determined everyday life for the native population. Detailed palaeopathological analysis of non-adult remains from Iron Age sites is of particular interest to determine how 'Romanisation' has shaped the distribution of health and disease. Unfortunately, skeletal samples dating to the Iron Age of both adults and children are sparse, making this an ever more challenging pursuit.

More comprehensive analysis of Romano-British child health with regards to the burial archaeology is recommended to allow us to pinpoint how status and possibly nuances in belief systems, not just between but also within sites, have shaped health profiles. Validation of the hypothesis of migration between rural and urban settlements can be attained via isotope analysis of older children in major urban cemeteries.

Overall, expansion of the current palaeopathological dataset, and integration with scientific techniques, particularly isotope analysis, and funerary archaeology will further aid in elucidating urban and rural lifeways in Roman Britain. Lastly, analysis of non-adult health in contemporary urban and rural cemeteries in continental Europe will provide parallels and analogies for the life and death of children in Roman Britain.

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UNIVERSITY OF READING

DYING YOUNG – A PALAEOPATHOLOGICAL ANALYSIS OF CHILD HEALTH IN ROMAN BRITAIN

Appendices

Submitted for the Degree of Doctor of Philosophy

DEPARTMENT OF ARCHAEOLOGY – SCHOOL OF ARCHAEOLOGY, GEOGRAPHY AND ENVIRONMENTAL SCIENCE

ANNA ROHNBOGNER

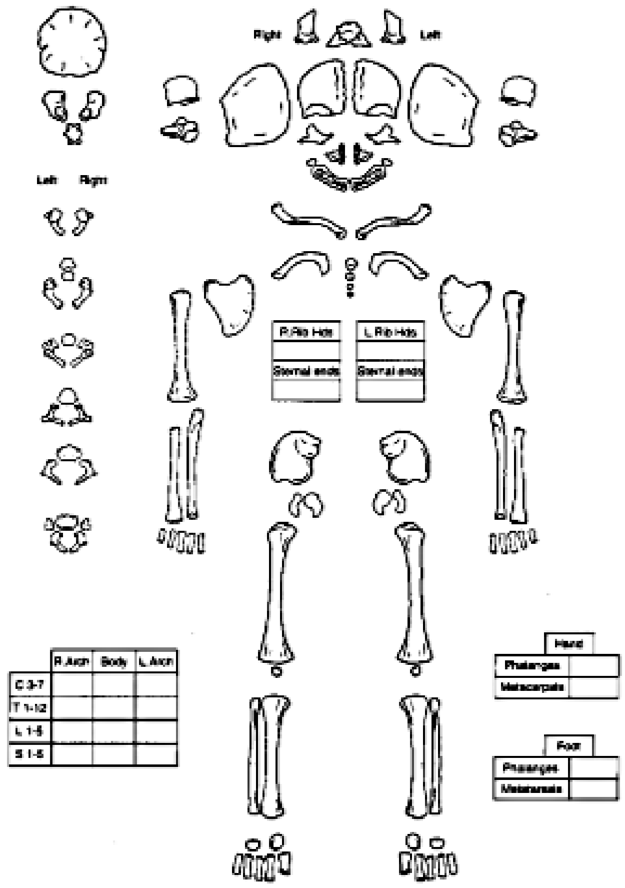
SEPTEMBER 2015

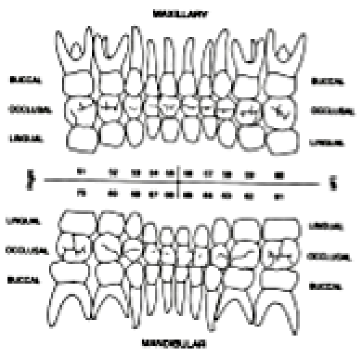
APPENDIX I

RECORDING FORM

Site code:	Skeleton number:	Age:

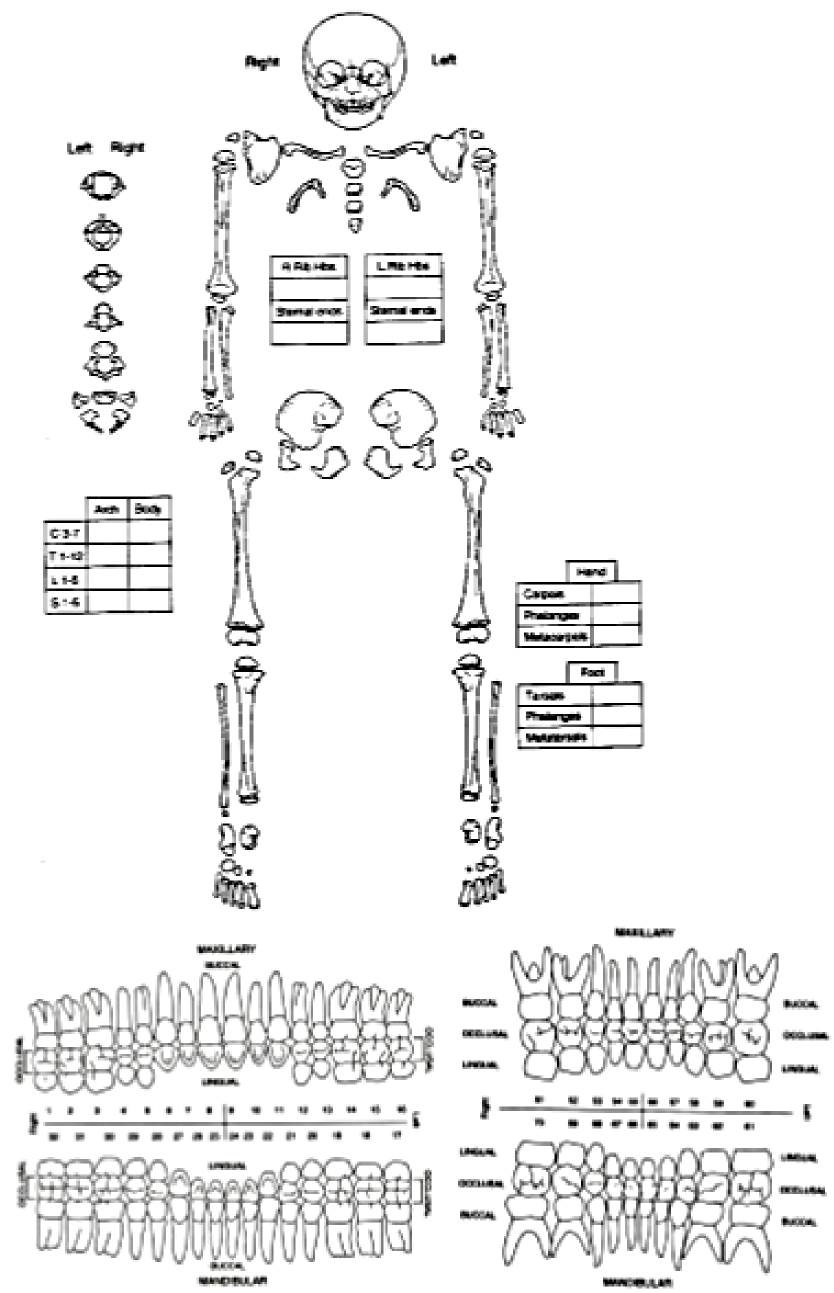
PERINATAL SKELETAL RECORDING FORM





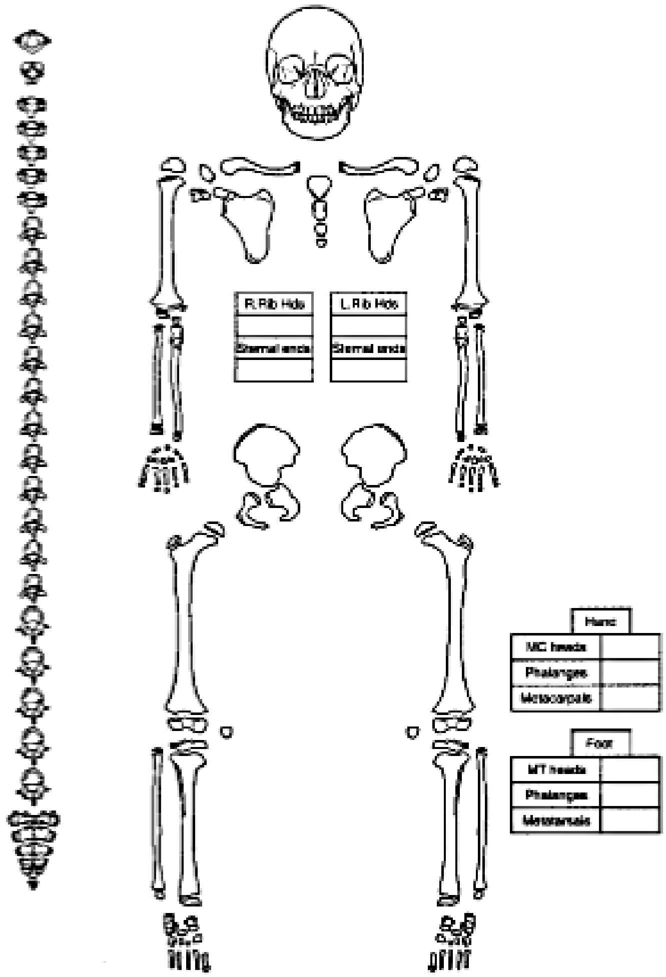
Site code:	Skeleton number:	Age:

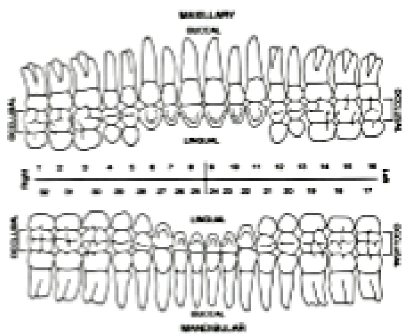
EARLY CHILDHOOD SKELETAL RECORDING FORM

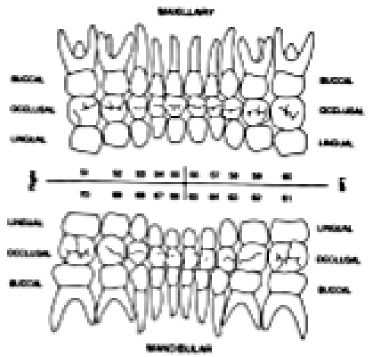


Site code:	Skeleton number:	Age:

LATE CHILDHOOD SKELETAL RECORDING FORM







Site code:	Skeleton number:	Age:

Element	Right	Left	Element	
Parietal			Occipital	
Temporal			Pars basilaris	
Maxilla			Ethmoid	
Nasal			Sphenoid	
Zygomatic			Fontanelle	
Lacrimal			Hyoid	
Palatine			Atlas	
Mandible			Axis	
Pars lateralis				
Frontal				

Element	No. of bodies	No. of right arches	No. of left arches
Cervical			
Thoracic			
Lumbar			
Sacrum			
Element	Right	Left	
Ribs			
Sternum	No. of sternebrae=		

Right

Element	Prox. Epi.	P 1/3	M 1/3	D 1/3	Dist. Epi.
Humerus					
Radius					
Ulna					
Femur					
Tibia					
Fibula					

Left

Element	Prox. Epi.	P 1/3	M 1/3	D 1/3	Dist. Epi.
Humerus					
Radius					
Ulna					
Femur					
Tibia					
Fibula					

Right

Element	>75%	75-50%	50-25%	<25%
Ilium				
Ischium				
Pubis				
Scapula				
Clavicle				
Patella				

Left

Element	>75%	75-50%	50-25%	<25%
Ilium				
Ischium				
Pubis				
Scapula				
Clavicle				
Patella				

Element	Number	Element	Number
Carpals		Tarsals	
Metacarpals		Metatarsals	
Hand phalanges		Foot phalanges	

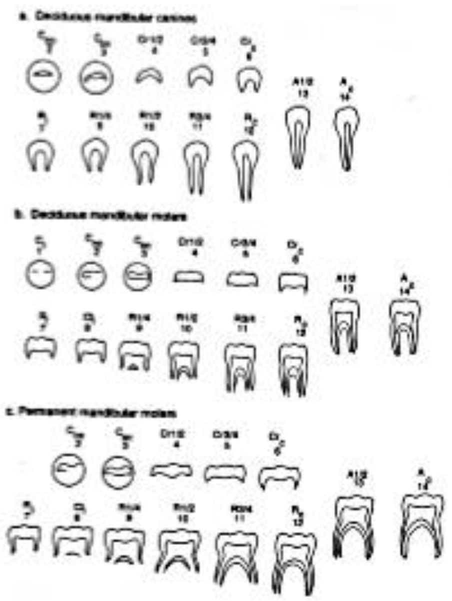
Additional unfused elements present:

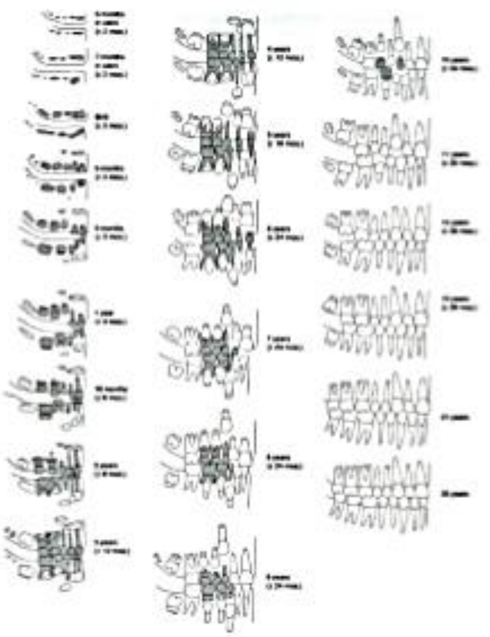
Site code:	Skeleton number:	Age:

Ageing I: Dental - mineralisation and eruption stages (Moorrees et al. 1963a, b and Ubelaker 1989)

	right					left				
Mandibular	dm2	dm1	dc	di2	di1	di1	di2	dc	dm1	dm2
Deciduous										

	right								left							
Mandibular	M3	M2	M1	P2	P1	C	I2	I1	I1	I2	C	P1	P2	M1	M2	M3
Permanent																





Formation of mandibular teeth (Moorrees et al. 1963a, b)			
Code	**Mineralisation stage**	**Code**	**Mineralisation stage**
1	Initial cusp formation	**8**	Initial cleft formation
2	Coalescence of cusps	**9**	Root length ¼
3	Cusp outline complete	**10**	Root length ½
4	Crown ½ complete	**11**	Root length ¾
5	Crown ¾ complete	**12**	Root length complete
6	Crown complete	**13**	Apex ½ closed
7	Initial root formation	**14**	Apex closed

Site code:	Skeleton number:	Age:

Ageing II: Fusion data   U = unfused , F = just fusing/partial fusion, C = complete fusion (Schaefer et al. 2009)

Perinate to young child

Element		Age at fusion	Stage
Sphenoid	Lesser wings to body	5f mnths- 1mnth	
	Pre-sphenoid to post-sphenoid	8f mnths-2 mnths	
	Greater wings to body	1-12 mnths	
	Foramen ovale	1-6 mnths	
Temporal	Tympanic ring to squama	Birth-1 mnth	
	Petromastoid to squamotympanic	Birth-1 yr	
Occipital	Supra-occipital to interparietal squama	5 f mnths	
	Superior median fissure	5-11 mnths	
	Sutura mendose	5 mnths-1.5 yrs	
	Pars lateralis to squama	1-4 yrs	
	Hypoglossal canal	1.5-4 yrs	
	Pars lateralis to pars basilaris	3-7 yrs	
Mandible	Mandibular symphysis	3-8 mnths	
Frontal	Fusion of 2 halves	Birth-2 yrs	
	Metopic suture obliteration	2-4 yrs	
Vertebrae	Intradental union	Full term	
	Neural arches C3-L5	6 mnths-2 yrs	
	Neural arches C2	3-4 yrs	
	Neural arches C1	4-5 yrs	
	Neural arches to centrum C3-L5	2-5 yrs	
	Dens to neural arch C2	3-4 yrs	
	Centrum to neural arch C2	4-6 yrs	
	Neural arch to anterior bar C1	4-5 yrs	
	Ossiculum terminale of dens	11-13 yrs	
Sacrum	Lateral element to neural arch	2-5 yrs	
	Wing to centra	2-6 yrs	
Pelvis	Ischiopubic ramus	5-11 years	
Humerus	Greater and lesser tubercles to head	2-6 yrs	

Older child to adolescent

Element		Age at fusion	Stage
Femur	Distal	14-19F, 16-20M	
	Proximal	14-17F, 16-19M	
	Greater trochanter	14-17F, 16-19M	
	Lesser trochanter	14-17F, 16-19M	
Tibia	Proximal	14-18F, 16-20M	
	Distal	14-17F, 16-19M	
	Tuberosity	13-15	
Fibula	Distal	14-17F, 15-20M	
	Proximal	14-17F, 16-20M	
Humerus	Proximal	14-19F, 16-21M	
	Medial epicondyle	13-15F, 16-18M	
	Distal	11-15F, 14-18M	
Radius	Distal	14-19F, 16-20M	
	Proximal	12-16F, 14-18M	
Ulna	Distal	15-19F, 17-20M	
	Proximal	12-15F, 14-18M	
Foot	Calcaneus	10-17F, 14-20M	
	Metatarsals and phalanges	11-13F, 14-16M	
Scapula	Coracoid-glenoid	14-18F, 15-18M	
	Acromion	15-17F, 17-20M	
	Inferior angle	17-22	
	Medial border	18-22	
Pelvis	Tri-radiate complex	11-15F, 14-18M	
	Ant inf iliac spine	14-18F, 16-18M	
	Ischial tuberosity	14-19F, 16-20M	
	Iliac crest	14-21F, 17-22M	
Sacrum	Auricular surface	15-21F, 17-20M	
	S1-S2 bodies	14-30+F, 19-30+M	
	S1-S2 alae	11-26F, 16-27M	
	S2-S5 bodies	12-26F, 16-28M	
	S2-S5 alae	10-19F, 16-20M	
Vertebrae	Annular rings	14-25	
Ribs	Heads	17-22	
Clavicle	Medial	17-30	
	Lateral	15-20	

Site code:	Skeleton number:	Age:

Ageing III: metric data (Fazekas and Kosa 1978, Scheuer et al. 1980 and Scheuer and Black 2000)

Pars basilaris and pars lateralis

Pars basilaris	Maximum width (mm)	Sagittal length (mm)	Maximum length (mm)

Pars lateralis	Maximum length (mm)	Maximum width (mm)

Pre-natal	MW<SL	<28f weeks	
	MW>SL	>30f weeks	
ML (basilaris) = ML (lateralis)		>28f weeks	
Post-natal	MW<SL	<3 months	
	MW>SL	>5 months	
Suggested age estimate			

Element	Left (mm)	Age range	Right (mm)	Age range
Humerus				
Radius				
Ulna				
Femur				
Tibia				

Method		Age range
Dental	Moorrees et al. (1963a, b)	
	Ubelaker (1989)	
Skeletal	Schaefer et al. (2009)	
	Scheuer and Black (2000)	
	Scheuer et al. (1980)	
	Fazekas and Kosa (1978)	
Final age range		

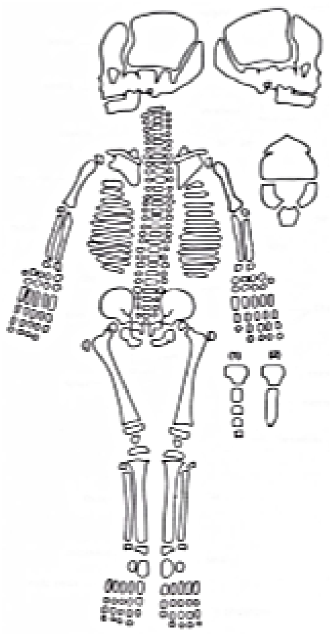
Site code:	Skeleton number:	Age:

Pathology

Element	**Comment**	**P/NP**
Cranial		
Orbital roof		
Mandible		
Enamel hypoplasia		
Dental pathology		
Frontal		
Parietals		
Occipital		
Sphenoid		
Zygomatic		
Maxilla		
Postcranial		
Vertebrae		
Ribs		
Dactylitis		
Scapula		
Osteomyelitis		
Periostitis		
Epiphyses		

Other palaeopathological observations:

Site code:	Skeleton number:	Age:



Additional information:

APPENDIX II

INSTRUCTIONS FOR MS ACCESS DATABASES

A total of three databases were created using Microsoft Access 2013:

- DATABASE 1: Combined sample database with a summary of the primary and secondary palaeopathological data in one table
- DATABASE 2: Primary sample database in one table
- DATABASE 3: Dental data for the primary study sample with one table and four queries

ABBREVIATIONS IN DATABASE 1 – COMBINED SAMPLE

Table: Combined sample

Column headings

- ID: primary key assigned as a unique identifier for each individual
- Site: Site name
  - Bantycock Mine
  - Barbraham Institute
  - Chesterton
  - Clarence Street (Leicester)
  - Dewlish villa
  - Dorchester-by-pass, A37 Western Link Road
  - Dorchester-by-pass, Maiden Castle Road
  - Frocester
  - Huntsman's Quarry
  - Lankhills (Winchester)
  - Poundbury (Camp, Dorchester)
  - Roman South (Southern cemetery, London)
  - Roman West (Western cemetery, London)
  - Springhead
  - Watersmeet
  - Trentholme Drive (York)

- Cannington
- Owslebury
- Bal15’94/Bal15/Bal (Baldock)
- Anc (Ancaster)
- Kings (Kingsholm Close, Gloucester)
- 35 Kings (35 Kingsholm Road, Gloucester)
- GPL (Gambier-Parry Lodge, Gloucester)
- Que1972/1982 (Quennsford Farm/Mill, Dorcherster-on-Thames)
- BH93 (Bradley Hill)
- CAT1 (Catsgore)
- Winch CHR/CF/NR/AR/StM/HS/VRW/VRE (Northen, Western and Eastern cemeteries of Winchester)
- GreatCast (Great Casterton)
- Dunstable
- Bath Gate (Cirencester)
- Ashton
- Butt Road (Colchester)

- Skeleton number: burial or skeleton number retrieved at the archive or in the skeletal/site report
- Period overview: early, mid or late Roman (Roman if no distinction could be made)
- Period: date of burial if available in centuries AD (cent=century)
- Reported age: age reported in the skeletal/site report (wks=weeks; mths=months; yrs=years)
- Overall age category: age category assigned in years (unless otherwise stated: wks=weeks)
- Pathology: information on any pathology reported by the author or discernible from the skeletal/site report; CO=cribra orbitalia; PH=porotic hyperostosis; EL=endocranial lesion; EH=enamel hypoplasia; TB=tuberculosis; OCD=osteochondritis dissecans; path=pathology

ABBREVIATIONS IN DATABASE 2 – PRIMARY SAMPLE

Table: Primary sample R-B children database

Column headings

- ID: primary key assigned as a unique identifier for each individual
- Site: site name (for abbreviations see above)
- Site type: see above
- Skeleton number: see above
- Period overview: see above
- Period: see above
- Reported age: see above
- Overall age category: see above
- Overall mean age: mean age (wks=weeks; mths=months; yrs=years)
- Dental development: root/crown development stages according to Moorrees et al. (1963a,b) (NP=not present; dm=deciduous molar; I=permanent incisor; C=canine; P=permanent premolar; M=permanent molar; see Table A6.1 for a definition of tooth formation stages)
- Dental age: age range provided by dental development
- Pars basilaris width: width of the pars basilaris in mm
- Pars basilaris sag length: sagittal length of the pars basilaris in mm
- Pars basilaris max length: maximum length of the pars basilaris in mm
- Pars lateralis width: width of the pars lateralis in mm
- Pars lateralis length: length of the pars lateralis in mm
- Pb/Pl age: age estimate given by measurements of the pars basilaris and pars lateralis (NP=not present; f wks= foetal weeks; wks=weeks; mths=months)
- Humerus: diaphyseal length of the humerus in mm (*in situ and excluded from analysis; proxF=proximal epiphysis fused; distF=distal epiphysis fused)
- Radius: diaphyseal length of the radius in mm (*in situ and excluded from analysis; proxF=proximal epiphysis fused; distF=distal epiphysis fused)
- Ulna: diaphyseal length of the ulna in mm (*in situ and excluded from analysis; proxF=proximal epiphysis fused; distF=distal epiphysis fused)
- Femur: diaphyseal length of the femur in mm (*in situ and excluded from analysis; proxF=proximal epiphysis fused; distF=distal epiphysis fused)
- Tibia: diaphyseal length of the tibia in mm (*in situ and excluded from analysis)

- LBL age: age estimate given by long bone measurements (wks=weeks; mths=months; yrs=years; *based on in situ measurements and excluded from analysis)
- Fusion data age: age estimate given by fusion data (NP=not present; wks=weeks; mths=months; yrs=years)
- Skull?: Y=yes/present (>25%); N=no/not present
- Orbits?: Y=yes/present (>25%); N=no/not present
- Mandible?: Y=yes/present (>25%); N=no/not present
- Hands/feet?: Y=yes/present (>25%); N=no/not present
- Spine?: Y=yes/present (>25%); N=no/not present
- Ribs?: Y=yes/present (>25%); N=no/not present
- Long bones?: Y=yes/present (>25%); N=no/not present
- Cribra orbitalia grade: NP=no orbits present for observation; 0=no cribrotic lesions observed; 3=Grade 3; 4=Grade 4; 5=Grade 5
- CO notes: further information on cribra orbitalia lesions; active/healed lesions; R=right; L=left; 0=no information
- Porotic hyperostosis: NP=no external skull surface present for observation; N=no porotic hyperostosis lesions observed; 2=Grade 2 (not included in analysis); 3=Grade 3; 4-Grade 4; 5=Grade 5
- PH notes: further information on porotic hyperostosis lesions; 0=no information
- Endocranial lesions: NP=no endocranial surface present for observation; N=no endocranial lesions observed; 1=Type 1; 2=Type 2; 3=Type 3; 4=Type 4
- EL notes: further information on endocranial lesions; R=right; L=left; 0=no information
- Enamel hypoplasia: Y=yes/enamel defects present; N=no enamel defects present; NP=no dentition present for observation
- EH notes: further information on enamel hypoplasia; number and types of teeth affected; R=right; L=left; 0=no information
- Rickets: Y=yes/diagnosis of rickets probable; N=no rickets; NP=no skeletal elements present to observe rachitic changes
- Rickets notes: further information on skeletal changes observed; R=right; L=left; 0=no information
- Scurvy: Y=yes/diagnosis of scurvy probable; N=no scurvy; NP=no skeletal elements present to observe scorbutic changes
- Scurvy notes: further information on skeletal changes observed; R=right; L=left; 0=no information

- Rib fractures/pathologies: Y=yes/skeletal changes observed in ribs; N=no pathological changes observed; NP=no ribs present for observation
- Ribs notes: further information on rib fractures or pathologies; R=right; L=left; 0=no information
- Osteopenia: Y=yes/diagnosis of osteopenia probable; N=no osteopenia; NP=no skeletal elements present to observe osteopenic changes
- Osteopenia notes: further information on probable osteopenic changes observed; 0=no information
- Long bone pathologies: Y=yes/pathological change in long bones observed; N=no pathological changes observed; NP=no long bones present for observation
- LB notes: further information on long bone pathologies; R=right; L=left; 0=no information
- Tuberculosis: Y=yes/diagnosis of tuberculosis probable; N=no tuberculosis; NP=no skeletal elements present to observe tuberculous skeletal changes
- Tuberculosis notes: further information on probable tuberculous skeletal changes; R=right; L=left; 0=no information
- Number of erupted teeth: total of erupted teeth present (NP=no teeth present; 0=no erupted teeth present)
- Deciduous teeth: total of erupted deciduous teeth present (NP=no deciduous teeth present; 0=no erupted deciduous teeth present)
- Permanent teeth: total of erupted permanent teeth present (NP=no permanent teeth present; 0=no erupted permanent teeth present)
- Anterior teeth: total of erupted anterior teeth present (NP=no anterior teeth present; 0=no erupted anterior teeth present)
- Posterior teeth: total of erupted posterior teeth present (NP=no posterior teeth present; 0=no erupted posterior teeth present)
- Dental disease: Y=Yes/dental disease observed; N=no dental disease observed; NP=no erupted dentition present for observation
- Dental notes: further information on dental disease observed; R=right; L=left; 0=no information; AM=antemortem; mand=mandibular; max=maxillary
- Other pathologies: notes on any additional skeletal changes observed; R=right; L=left; N=none observed
- Location in cemetery: information on the burial location; main=main cemetery
- Grave feature: information on the burial position or particular feature of the burial
- Grave goods: information on any grave goods reported

- Coffin: Y=yes/coffin present; N=no/coffin absent; slab-lined=slab-lined grave
- Alignment: E=east; W=west; N=north; S=south
- Further burial information: any additional burial information
- Summary: summary of specific skeletal changes observed
- Pathology: overview of probable diagnoses for individual skeletal changes observed
- Photos taken: Y=yes; N=no
- X-rays taken: Y=yes; N=no

ABBREVIATIONS IN DATABASE 3 – DENTAL DATA

Table: Dental data

Column headings

- ID: primary key assigned as a unique identifier for each individual
- Site: site name (for abbreviations of site names see above)
- Site type: settlement type (for description see above)
- Skeleton number: burial or skeleton number retrieved at the archive
- Overall age category: age group (for description see above)
- Overall mean age: mean age (for description see above)
- Dental development: root/crown development stages according to Moorrees et al. (1963a,b) (for abbreviations see above)
- Dental age: age range provided by dental development
- Enamel hypoplasia: presence/absence of enamel hypoplasia (for abbreviations see above)
- EH notes: comments on enamel hypoplasia, number and type of teeth affected
- Number of erupted teeth: total of erupted teeth present (NP=no teeth present; 0=no erupted teeth present)
- Deciduous teeth: total of erupted deciduous teeth present (NP=no deciduous teeth present; 0=no erupted deciduous teeth present)
- Dec ant: total of erupted anterior deciduous teeth present (NP=no anterior deciduous teeth present; 0=no erupted anterior deciduous teeth present)
- Dec post: total of erupted posterior deciduous teeth present (NP=no posterior deciduous teeth present; 0=no erupted posterior deciduous teeth present)
- Permanent teeth: total of erupted permanent teeth present (NP=no permanent teeth present; 0=no erupted permanent teeth present)

- <u>Perm ant:</u> total of erupted anterior permanent teeth present (NP=no anterior permanent teeth present; 0=no erupted anterior permanent teeth present)
- <u>Perm post:</u> total of erupted posterior permanent teeth present (NP=no posterior permanent teeth present; 0=no erupted posterior permanent teeth present)
- <u>Anterior teeth:</u> total of erupted anterior teeth present (NP=no anterior teeth present; 0=no erupted anterior teeth present)
- <u>Posterior teeth:</u> total of erupted posterior teeth present (NP=no posterior teeth present; 0=no erupted posterior teeth present)
- <u>Dental disease:</u> see above
- <u>Dental notes:</u> see above

Query 1 – Anterior and posterior dentition: query for erupted anterior and posterior teeth by site type

Query 2 – Anterior dentition: query for erupted deciduous and permanent anterior teeth

Query 3 – Individuals over 1 year: query for age groups, site types and erupted teeth in individuals aged between 1.1-17.0 years

Query 4 – Posterior dentition: query for erupted deciduous and permanent posterior teeth

APPENDIX III

DENTAL DEVELOPMENT AND DISEASE

A3.1. Tooth formation stages

Symbol	Description
Cui	Initial cusp formation
Ccocu/Coc	Coalescence of cusps
Cu out/Coc	Cusp outline complete
C ½/Cr ½	Crown half complete
C ¾/Cr ¾	Crown three-quarters complete
Cc/Crc	Crown complete
Ri	Initial root formation
Clefti/Cli	Initial cleft formation
R ¼	Root length one quarter
R ½	Root length half
R 2/3	Root length two thirds
R ¾	Root length three quarters
Rc	Root complete
A ½	Apex half closed
Ac	Apex closed

A3.2. Formation stages of the permanent dentition averaged for males and females from Moorrees et al. (1963a) and tabulated after Smith (1991) in years

Formation stage	I1	I2	C	P1	P2	M1	M2	M3
Ci			0.5	1.8	3	0	3.6	9.4
Cco			0.7	2.3	3.5	0.2	3.8	9.9
Coc			1.3	2.9	4.2	0.6	4.4	10.5
Cr ½			2.0	3.6	4.7	1.0	4.9	11.1
Cr ¾			2.9	4.4	5.4	1.5	5.5	11.6
Crc			4.0	5.1	6.2	2.2	6.3	12.1
Ri			4.7	5.8	6.8	2.7	7.0	12.8
Cli						3.5	7.8	13.6
R ¼	4.5	5.0	5.5	6.7	7.6	4.5	9.3	14.6
R ½	5.2	5.7	7.5	8.4	9.1	5.1	9.9	15.4
R 2/3	5.7	6.4						
R ¾	6.5	6.9	8.9	9.5	10.4	5.8	10.9	16.4
Rc	6.9	7.8	9.5	10.2	11.1	6.1	11.4	16.9
A ½	7.3	8.3	10.8	11.5	12.3	7.3	12.7	18.2
Ac	7.9	8.9	12.1	12.8	14.0	9.0	14.7	20.3

A3.3. Formation stages of the deciduous dentition averaged for males and females from Moorrees et al. (1963b) in years

Formation stage	dc	dm1	dm2
Cco	0	0	0
Coc	0	0	0
Cr ½	0.3	0	0.3
Cr ¾	0.5	0.3	0.5
Crc	0.8	0.4	0.8
Ri	0.8	0.5	1.0
Cli		0.6	1.4
R ¼	1.0	0.8	1.5
R ½	1.3	0.9	1.6
R ¾	1.8	1.2	1.9
Rc	2	1.2	2.0
A ½	2.5	1.5	2.5
Ac	3.0	1.8	2.9

A3.4. Number of teeth from different settlement contexts

Site (date in century AD)	Individuals N	Deciduous teeth (n)	Permanent teeth (n)	Anterior teeth (n)	Posterior teeth (n)	Total N
Major urban						
Colchester (Butt Road) (4th-5th)	80	530	679	506	703	**1209**
Winchester (Northern, Western, Eastern cemeteries) (1st-4th)	39	268	291	245	314	**559**
Cirencester (Bath Gate) (4th)	38	139	344	172	311	**483**
York (Trentholme Drive) (3rd-4th)	17	36	226	85	177	**262**
Gloucester (Kingsholme Road/Close, Gambier-Parry Lodge) (2nd-4th)	15	102	109	92	119	**211**
Major urban N	**189**	**1075**	**1649**	**1100**	**1624**	**2724**
Minor urban						
Queenford Farm/Mill (3rd-4th)	51	391	338	316	413	**729**
Ancaster (3rd-4th)	34	321	159	206	274	**480**
Baldock (2nd-4th)	25	193	221	205	209	**414**
Great Casterton (3rd-4th)	27	281	102	154	229	**383**
Ashton (4th)	17	138	127	116	149	**265**
Dunstable (3rd-5th)	12	30	171	72	129	**201**
Minor urban N	**166**	**1354**	**1118**	**1069**	**1403**	**2472**
Rural						
Cannington (3rd-4th)	69	388	589	374	603	**977**
Bradley Hill (4th-5th)	5	62	0	32	30	**62**
Owslebury (1st-4th)	3	25	17	19	23	**42**
Catsgore (2nd-5th)	1	6	0	3	3	**6**
Rural N	**78**	**481**	**606**	**428**	**659**	**1087**
Total N	**433**	**2910**	**3373**	**2597**	**3686**	**6283**

APPENDIX IV

SPSS OUTPUT - GROWTH

Humeral growth: Romano-British and modern non-adults

Two-Sample Kolmogorov-Smirnov Test

Frequencies

	groupnum	N
humerus	1.00	17
	2.00	17
	Total	34

Test Statistics[a]

		humerus
Most Extreme Differences	Absolute	.294
	Positive	.294
	Negative	-.059
Kolmogorov-Smirnov Z		.857
Asymp. Sig. (2-tailed)		.454

a. Grouping Variable: groupnum

Radial growth: Romano-British and modern non-adults

Two-Sample Kolmogorov-Smirnov Test

Frequencies

	groupnum	N
radius	1.00	16
	2.00	16
	Total	32

Test Statistics[a]

		radius
Most Extreme Differences	Absolute	.250
	Positive	.250
	Negative	.000
Kolmogorov-Smirnov Z		.707
Asymp. Sig. (2-tailed)		.699

a. Grouping Variable: groupnum

Ulnar growth: Romano-British and modern non-adults

Two-Sample Kolmogorov-Smirnov Test

Frequencies

	groupnum	N
ulna	1.00	16
	2.00	16
	Total	32

Test Statistics[a]

		ulna
Most Extreme Differences	Absolute	.250
	Positive	.250
	Negative	.000
Kolmogorov-Smirnov Z		.707
Asymp. Sig. (2-tailed)		.699

a. Grouping Variable: groupnum

Femoral growth: Romano-British and modern non-adults

Two-Sample Kolmogorov-Smirnov Test

Frequencies

	groupnum	N
femur	1.00	16
	2.00	16
	Total	32

Test Statistics[a]

		femur
Most Extreme Differences	Absolute	.313
	Positive	.313
	Negative	.000
Kolmogorov-Smirnov Z		.884
Asymp. Sig. (2-tailed)		.415

a. Grouping Variable: groupnum

Tibial growth: Romano-British and modern non-adults

Two-Sample Kolmogorov-Smirnov Test

Frequencies

	groupnum	N
tibia	1.00	16
	2.00	16
	Total	32

Test Statistics[a]

		tibia
Most Extreme Differences	Absolute	.313
	Positive	.313
	Negative	-.063
Kolmogorov-Smirnov Z		.884
Asymp. Sig. (2-tailed)		.415

a. Grouping Variable: groupnum

Femoral growth: major urban, minor urban and rural non-adults

Kruskal-Wallis Test

Ranks

	site	N	Mean Rank
allfemur	1.00	16	109.50
	2.00	99	94.38
	3.00	80	100.18
	Total	195	

Test Statistics[a,b]

	allfemur
Chi-Square	1.190
df	2
Asymp. Sig.	.552

a. Kruskal Wallis Test

b. Grouping Variable: site

```
*Nonparametric Tests: Independent Samples.
NPTESTS
  /INDEPENDENT TEST (allfemur) GROUP (site)
KRUSKAL_WALLIS(COMPARE=PAIRWISE)
  /MISSING SCOPE=ANALYSIS USERMISSING=EXCLUDE
  /CRITERIA ALPHA=0.05  CILEVEL=95.
```

Nonparametric Tests

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of allfemur is the same across categories of site.	Independent-Samples Kruskal-Wallis Test	.552	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Femoral growth: in individuals with and without cribra orbitalia

Two-Sample Kolmogorov-Smirnov Test

Frequencies

	CO	N
femur	.00	34
	1.00	94
	Total	128

Test Statistics[a]

		femur
Most Extreme Differences	Absolute	.250
	Positive	.250
	Negative	-.011
Kolmogorov-Smirnov Z		1.248
Asymp. Sig. (2-tailed)		.089

a. Grouping Variable: CO

Femoral growth: in individuals with and without enamel hypoplasia

Two-Sample Kolmogorov-Smirnov Test

Frequencies

	EH	N
femur2	.00	43
	1.00	103
	Total	146

Test Statistics[a]

		femur2
Most Extreme Differences	Absolute	.317
	Positive	.317
	Negative	-.002
Kolmogorov-Smirnov Z		1.745
Asymp. Sig. (2-tailed)		.005

a. Grouping Variable: EH

Femoral growth: in individuals with and without new bone formation

Two-Sample Kolmogorov-Smirnov Test

Frequencies

	NB	N
femurNB	.00	26
	1.00	157
	Total	183

Test Statistics[a]

		femurNB
Most Extreme Differences	Absolute	.221
	Positive	.221
	Negative	-.095
Kolmogorov-Smirnov Z		1.045
Asymp. Sig. (2-tailed)		.225

a. Grouping Variable: NB

Femoral growth: in individuals with and without metabolic disease (vitamin C/D deficiency)

Two-Sample Kolmogorov-Smirnov Test

Frequencies

	metaproper	N
femurmeta	.00	10
	1.00	134
	Total	144

Test Statistics[a]

		femurmeta
Most Extreme Differences	Absolute	.406
	Positive	.018
	Negative	-.406
Kolmogorov-Smirnov Z		1.238
Asymp. Sig. (2-tailed)		.093

a. Grouping Variable: metaproper

Femoral growth: Romano-British and post-medieval non-adults

Two-Sample Kolmogorov-Smirnov Test

Frequencies

	RB	N
femur4	.00	84
	1.00	157
	Total	241

Test Statistics[a]

		femur4
Most Extreme Differences	Absolute	.394
	Positive	.000
	Negative	-.394
Kolmogorov-Smirnov Z		2.916
Asymp. Sig. (2-tailed)		.000

a. Grouping Variable: RB

APPENDIX V

SPSS OUTPUT – AGE-AT-DEATH

Age-at-death: cribra orbitalia in major urban non-adults

Two-Sample Kolmogorov-Smirnov Test

Frequencies

	COurban	N
ageCOurban	.00	305
	1.00	35
	Total	340

Test Statistics[a]

		ageCOurban
Most Extreme Differences	Absolute	.435
	Positive	.435
	Negative	-.017
Kolmogorov-Smirnov Z		2.436
Asymp. Sig. (2-tailed)		.000

a. Grouping Variable: COurban

Age-at-death: cribra orbitalia in minor urban non-adults

Two-Sample Kolmogorov-Smirnov Test

Frequencies

	COtown	N
ageCOtown	.00	263
	1.00	40
	Total	303

Test Statistics[a]

		ageCOtown
Most Extreme Differences	Absolute	.506
	Positive	.506
	Negative	-.023
Kolmogorov-Smirnov Z		2.979
Asymp. Sig. (2-tailed)		.000

a. Grouping Variable: COtown

Age-at-death: cribra orbitalia in rural non-adults

Two-Sample Kolmogorov-Smirnov Test

Frequencies

	COrural	N
ageCOrural	.00	140
	1.00	30
	Total	170

Test Statistics[a]

		ageCOrural
Most Extreme Differences	Absolute	.531
	Positive	.531
	Negative	.000
Kolmogorov-Smirnov Z		2.639
Asymp. Sig. (2-tailed)		.000

a. Grouping Variable: COrural

Age-at-death: enamel hypoplasia in major urban non-adults

Two-Sample Kolmogorov-Smirnov Test

Frequencies

	EHurban	N
ageEHurban	.00	149
	1.00	54
	Total	203

Test Statistics[a]

		ageEHurban
Most Extreme Differences	Absolute	.298
	Positive	.298
	Negative	-.023
Kolmogorov-Smirnov Z		1.878
Asymp. Sig. (2-tailed)		.002

a. Grouping Variable: EHurban

Age-at-death: enamel hypoplasia in minor urban non-adults

Two-Sample Kolmogorov-Smirnov Test

Frequencies

	EHtown	N
ageEHtown	.00	143
	1.00	43
	Total	186

Test Statistics[a]

		ageEHtown
Most Extreme Differences	Absolute	.383
	Positive	.383
	Negative	-.021
Kolmogorov-Smirnov Z		2.200
Asymp. Sig. (2-tailed)		.000

a. Grouping Variable: EHtown

Age-at-death: enamel hypoplasia in rural non-adults

Two-Sample Kolmogorov-Smirnov Test

Frequencies

	EHrural	N
ageEHrural	.00	83
	1.00	12
	Total	95

Test Statistics[a]

		ageEHrural
Most Extreme Differences	Absolute	.628
	Positive	.628
	Negative	-.024
Kolmogorov-Smirnov Z		2.032
Asymp. Sig. (2-tailed)		.001

a. Grouping Variable: EHrural

Age-at-death: endocranial lesions in major urban non-adults

Two-Sample Kolmogorov-Smirnov Test

Frequencies

	ELurban	N
ageELurban	.00	254
	1.00	12
	Total	266

Test Statistics[a]

		ageELurban
Most Extreme Differences	Absolute	.256
	Positive	.256
	Negative	-.084
Kolmogorov-Smirnov Z		.866
Asymp. Sig. (2-tailed)		.441

a. Grouping Variable: ELurban

Age-at-death: endocranial lesions in minor urban non-adults

Two-Sample Kolmogorov-Smirnov Test

Frequencies

	ELtown	N
ageELtown	.00	193
	1.00	43
	Total	236

Test Statistics[a]

		ageELtown
Most Extreme Differences	Absolute	.249
	Positive	.249
	Negative	-.097
Kolmogorov-Smirnov Z		1.475
Asymp. Sig. (2-tailed)		.026

a. Grouping Variable: ELtown

Age-at-death: endocranial lesions in rural non-adults

Two-Sample Kolmogorov-Smirnov Test

Frequencies

	ELrural	N
ageELrural	.00	104
	1.00	17
	Total	121

Test Statistics[a]

		ageELrural
Most Extreme Differences	Absolute	.269
	Positive	.269
	Negative	-.110
Kolmogorov-Smirnov Z		1.029
Asymp. Sig. (2-tailed)		.240

a. Grouping Variable: ELrural

Age-at-death: new bone formation in major urban non-adults

Two-Sample Kolmogorov-Smirnov Test

Frequencies

	NBurban	N
ageNBurban	.00	319
	1.00	23
	Total	342

Test Statistics[a]

		ageNBurban
Most Extreme Differences	Absolute	.396
	Positive	.396
	Negative	-.013
Kolmogorov-Smirnov Z		1.833
Asymp. Sig. (2-tailed)		.002

a. Grouping Variable: NBurban

Age-at-death: new bone formation in minor urban non-adults

Two-Sample Kolmogorov-Smirnov Test

Frequencies

	NBtown	N
ageNBtown	.00	278
	1.00	16
	Total	294

Test Statistics[a]

		ageNBtown
Most Extreme Differences	Absolute	.375
	Positive	.375
	Negative	-.036
Kolmogorov-Smirnov Z		1.459
Asymp. Sig. (2-tailed)		.028

a. Grouping Variable: NBtown

Age-at-death: new bone formation in rural non-adults

Two-Sample Kolmogorov-Smirnov Test

Frequencies

	NBrural	N
ageNBrural	.00	156
	1.00	11
	Total	167

Test Statistics[a]

		ageNBrural
Most Extreme Differences	Absolute	.500
	Positive	.500
	Negative	-.049
Kolmogorov-Smirnov Z		1.603
Asymp. Sig. (2-tailed)		.012

a. Grouping Variable: NBrural

Age-at-death: metabolic disease in major urban non-adults

Two-Sample Kolmogorov-Smirnov Test

Frequencies

	Murb2	N
Murb1	.00	214
	1.00	17
	Total	231

Test Statistics[a]

		Murb1
Most Extreme Differences	Absolute	.441
	Positive	.000
	Negative	-.441
Kolmogorov-Smirnov Z		1.749
Asymp. Sig. (2-tailed)		.004

a. Grouping Variable: Murb2

Age-at-death: metabolic disease in minor urban non-adults

Two-Sample Kolmogorov-Smirnov Test

Frequencies

	mtow2	N
mtow1	.00	200
	1.00	18
	Total	218

Test Statistics[a]

		mtow1
Most Extreme Differences	Absolute	.448
	Positive	.000
	Negative	-.448
Kolmogorov-Smirnov Z		1.822
Asymp. Sig. (2-tailed)		.003

a. Grouping Variable: mtow2

Age-at-death: metabolic disease in rural non-adults

Two-Sample Kolmogorov-Smirnov Test

Frequencies

	mru2	N
mru1	.00	95
	1.00	20
	Total	115

Test Statistics[a]

		mru1
Most Extreme Differences	Absolute	.303
	Positive	.100
	Negative	-.303
Kolmogorov-Smirnov Z		1.230
Asymp. Sig. (2-tailed)		.097

a. Grouping Variable: mru2

APPENDIX VI

DIAPHYSEAL LENGTHS

A6.1. Humerus

Age (yrs)	**Major urban**		**Minor urban**		**Rural**		**Total**	**Mean length**
	N	*Length (mm)*	*N*	*Length (mm)*	*N*	*Length (mm)*	***N***	***Length (mm)***
1			6	106.7	1	116	**7**	**108**
2	8	120	13	130.08	4	111.25	**25**	**124**
3	4	135.25	3	145.33	1	136	**8**	**139**
4	2	138	4	147.5			**6**	**144**
5	4	152.75	10	157.9			**14**	**156**
6	7	171.29	11	176.55	1	148	**19**	**173**
7	4	177.25	5	183.6			**9**	**181**
8	6	203	1	180			**7**	**200**
9	3	209.33	2	205	2	213.5	**7**	**209**
10	3	218.3	3	216.7			**6**	**218**
11	7	225.57	3	236	1	229	**11**	**229**
12	4	243.25	3	240.7	2	220.5	**9**	**237**
13	2	242	2	241.5			**4**	**242**
14	5	242.4	4	251.25			**9**	**246**
15	3	261.3	1	268			**4**	**266**
16			1	262	2	268.5	**3**	**266**
17	1	271					**1**	**271**
Total	**63**		**72**		**14**		**149**	

A6.2. Radius

Age (yrs)	**Major urban**		**Minor urban**		**Rural**		**Total**	**Mean length**
	N	*Length (mm)*	*N*	*Length (mm)*	*N*	*Length (mm)*	***N***	***Length (mm)***
1			5	81.8			**5**	**82**
2	5	91.8	12	92.5	1	80	**18**	**92**
3	2	95.5	3	97.67	1	102	**6**	**98**
4	2	97	3	107.67	1	105	**6**	**104**
5	3	111.67	9	116.89			**12**	**116**
6	4	135.25	9	127.33	1	113	**14**	**129**
7	4	143	4	131.5			**8**	**137**
8	4	145.75	1	136			**5**	**144**
9	1	138	2	153			**3**	**148**
10	1	160	3	159			**4**	**159**
11	5	154.8	2	175	1	171	**8**	**162**
12	4	182	2	183.5	1	148	**7**	**178**
13	1	190	2	181.5			**3**	**184**
14	3	182	4	179.75	1	207	**8**	**184**
15	4	200.25	1	182			**5**	**197**
16			1	183	2	197.5	**3**	**193**
Total	**43**		**63**		**9**		**115**	

A6.3. Ulna

Age (yrs)	Major urban		Minor urban		Rural		Total	Mean length
	N	*Length (mm)*	*N*	*Length (mm)*	*N*	*Length (mm)*	***N***	***Length (mm)***
1			6	90.83			**6**	**90**
2	4	101.25	11	104.09	2	92.5	**17**	**102**
3	4	112.5	3	103	1	114	**8**	**109**
4	2	108.5	3	119.67			**5**	**115**
5	2	124	9	129.89			**11**	**129**
6	2	133	7	140			**9**	**138**
7	3	160.67	3	146			**6**	**153**
8	5	167					**5**	**167**
9	1	152	2	167.5	1	170	**4**	**164**
10	1	177	3	174.33			**4**	**175**
11	6	176.67			1	184	**7**	**178**
12	3	201.67	1	202			**4**	**202**
13	3	208.67	3	205.67			**6**	**207**
14	1	192	2	197			**3**	**195**
15	2	231					**2**	**231**
Total	**39**		**53**		**5**		**97**	

A6.4. Femur

Age (yrs)	Major urban		Minor urban		Rural		Total	Mean length
	N	*Length (mm)*	*N*	*Length (mm)*	*N*	*Length (mm)*	***N***	***Length (mm)***
1			4	139.5	1	148	**5**	**141**
2	6	153	13	162.23	3	140.3	**22**	**157**
3	3	185.22	3	177	1	174	**7**	**179**
4	2	182.5	4	198.75			**6**	**185**
5	4	208.75	11	214.09			**15**	**213**
6	5	240	11	233.82			**16**	**236**
7	2	251	5	244.4			**7**	**246**
8	8	278.13	2	247			**10**	**272**
9	2	283.5	3	271			**5**	**276**
10	2	303.5	3	317			**5**	**213**
11	6	302.83	2	344	1	321	**9**	**314**
12	4	340.25	4	341.25	1	282	**9**	**334**
13	2	331.5	2	345			**4**	**338**
14	1	334	4	348.5	1	365	**6**	**348**
15	4	343.25	2	355	1	376	**7**	**351**
16	2	365	2	363	1	373	**5**	**366**
Total	**53**		**75**		**10**		**138**	

A6.5. Tibia

Age	Major urban		Minor urban		Rural		Total	Mean length
	N	*Length (mm)*	*N*	*Length (mm)*	*N*	*Length (mm)*	***N***	***Length (mm)***
1	1	122	5	107.6			**6**	**110**
2	6	127	10	134.6	2	110.5	**18**	**129**
3	3	148.67	4	137.25	1	138	**8**	**142**
4	2	144.5	4	161.75	1	156	**7**	**156**
5	3	170.33	11	172.73			**14**	**172**
6	8	184.63	11	185.55			**19**	**185**
7	2	208	4	196.5			**6**	**200**
8	6	219.33	2	213.5			**8**	**218**
9	2	224.5	1	205	1	233	**4**	**222**
10	1	259	4	238.5			**5**	**243**
11	7	232.29	2	276.5	2	239	**11**	**242**
12	5	269.4	4	275.5			**9**	**272**
13	4	274.25	2	272.5			**6**	**274**
14	1	278	2	259.5	1	306	**4**	**276**
15	5	298	2	283.5	1	335	**8**	**299**
16	2	295.5	2	288	1	314	**5**	**296**
Total	**58**		**70**		**10**		**138**	

A6.6. Mean diaphyseal lengths in mm based on Maresh (1955)

Age (yrs)	HUMERUS	RADIUS	ULNA	FEMUR	TIBIA
1	104	80	90	135	108
2	129	97	108	170	139
3	146	109	122	199	162
4	162	121	134	226	182
5	176	132	146	246	201
6	190	141	156	269	219
7	203	151	166	291	237
8	215	160	176	312	252
9	228	169	185	331	269
10	240	178	195	349	285
11	253	187	205	368	301
12	265	197	215	395	318
13	279	207	227	406	332
14	292	218	238	423	346
15	303	226	247	435	356
16	310	231	253	441	361
17	326	245	269	459	378

A6.7. Diaphyseal lengths in mm by site type

Age (years)	Major urban	Minor urban	Rural
0.2			82.8
0.25	85.62		
0.25	87		
0.25	75.07		
0.25	83.73		
0.25	88.96		
0.25	81.96		
0.25	86.23		
0.45		100.42	
0.5		98.74	
0.5		96	
0.5	94.27		
0.5	83.41		
0.6		100.7	
0.75		97	
0.75		121	
1			148
1		138	
1	93.28		
1	97.51		
1.25			137.5
1.5		135	
1.5		144	
1.5		132	
1.5		144	
1.5		148	
1.5	150		
1.5	146		
1.5	121		
2			153
2			130
2		165	
2		152	
2		161	
2		166	
2	165		
2	159		
2.5			168.5
2.5		118	
2.5		157	
2.5		161	
2.5		190	
2.5		180	
2.5		176	
2.5		200	
2.5	177		

2.5	162		
3			173.52
3		168	
3		159	
3		210	
3		192	
3		178	
3		160	
3		160	
3	208		
3	163		
3	179		
3	186		
3.5		222	
3.5	179		
4		215	
4		177	
4		198	
4		130.9	
4		152	
4		205	
4	186		
4	189		
4.5		175	
5		187	
5		216	
5		214	
5		224	
5		237	
5		235	
5		199	
5		241	
5		190	
5	248		
5	194		
5	223		
5	196		
5	218		
5	198		
5.5		225	
5.5		199	
5.5		234	
5.5		240	
5.5		267	
5.5	210		
6		226	
6		214	
6		231	
6		231	

6		207	
6		270	
6		241	
6		235	
6	259		
6	239		
6	239		
6	262		
6	242		
6	230		
6.5		243	
7		278	
7		213	
7		252	
7		230	
7	276		
7	226		
7.5		249	
7.5	247		
8		209	
8		285	
8	291		
8	273		
8	250		
8	333		
8	254		
8	285		
8	289		
8	294		
8	274		
8.5		254	
9		301	
9		258	
9	307.5		
9	269		
9	259		
9.5		331	
10		308	
10		312	
10	326		
10	341		
10.5	266		
11			320.5
11		329	
11		323	
11	327		
11	260		
11	294		
11	295		

11	323		
11	318		
11.5		359	
11.5	336		
12			282
12		349	
12		325	
12		340	
12		351	
12	324		
12	352		
12	349		
12.5	351		
12.5	330		
13			352
13		345	
13.5		345	
13.5		362	
13.5		291	
13.5		359	
13.5	333.2		
14			391
14			365.2
14		301	
14		372	
14		375	
14	334		
14.5		387	
15			375.8
15		347	
15		371	
15		363	
15	329		
15	343		
15	347		
15	439		
15	339		
15.5		421	
15.5		357	
15.5		387	
15.5	362		
16			361
16		343	
16		383	
16	345		
16	385		
16	381		
16.5			373.2
16.5			358

16.5	364.5

A6.8. Femoral diaphyseal lengths of non-adults with and without enamel hypoplasia

Age (yrs)	With enamel hypoplasia	Without enamel hypoplasia
0.2		79.95
0.3		75.07
0.3		81.96
0.3		82.8
0.3		83.73
0.3		85.62
0.3		86.23
0.3		88.96
0.4		83.41
0.4		98.74
0.4		100.42
0.5		94.27
0.5		96
0.6		100.7
0.8		121
1		138
1.3		132
1.3	144	
1.3		144
1.5		130
1.5		137.5
1.5		146
1.5		148
1.5		150
1.6		148
1.8		152
1.8		161
1.8		165
1.8		165
1.8	166	
2	159	
2.5	118	
2.5		159
2.5		161
2.5		162
2.5		176
2.5	177	
2.5		180
2.5		190
2.5		200
2.8		186

3		153
3		173.52
3		192
3		208
3.3		222
3.5		179
3.8		198
3.8	216	
4		177
4		186
4		215
4.3	205	
4.8		175
4.8		196
5	198	
5		199
5	214	
5		218
5		223
5	235	
5	241	
5.3		237
5.3		240
5.5		199
5.5	210	
5.5		224
5.5		225
5.8		226
5.8		234
5.8	241	
5.8		262
6	214	
6		231
6.3	231	
6.3		235
6.3	239	
6.5		230
6.5	243	
7		213
7		252
7		259
7	276	
7		278
7.3	226	
7.5	247	
7.5	249	
7.5		273
7.8		254
7.8		270

8		209
8		285
8		289
8		333
8.3		285
8.3		294
9	259	
9		294
9		301
9.3		258
9.5	331	
9.8	308	
10		307.5
10		312
10.5		266
10.5	327	
10.8	323	
11		260
11	295	
11		318
11		320.5
11	329	
11.3	349	
11.3		359
11.5	336	
12		324
12		340
12	365.2	
12.3		325
12.3		345
12.3	349	
12.3		352
12.5		330
13	329	
13.3	363	
13.5	345	
13.5		359
13.5		362
13.7	372	
13.8	334	
13.8		343
14	301	
14		339
14		347
14.5		387
14.8	371	
15		358
15		373.2
15		375.8

15.5	362	
15.5	387	
15.5	421	
16	343	
16		345
16.3		383
16.3		385

A6.9. Femoral lengths in individuals with and without periosteal new bone formation

Age (yrs)	with new bone formation	without new bone formation
0.5		94.27
0.5		96
0.6		100.7
0.75		121
0.75		97
1		148
1		138
1		97.51
1		93.28
1.25		137.5
1.5		135
1.5		144
1.5		148
1.5		144
1.5		132
1.5		150
1.5	121	
1.5		146
2		153
2		130
2		152
2		165
2	161	
2		166
2		165
2		159
2.5		168.5
2.5		190
2.5		118
2.5		157
2.5		161
2.5		200
2.5		176
2.5		180

2.5		177
2.5		162
3	173.52	
3		159
3		160
3	178	
3		168
3		192
3		210
3		160
3		179
3	186	
3		163
3		208
3.5		222
3.5		179
4	205	
4		215
4		198
4		130.9
4		177
4		152
4		189
4		186
4.5		175
5		241
5		187
5	235	
5		224
5		237
5		216
5		199
5		214
5		190
5		218
5		198
5		223
5		196
5		248
5		194
5.5		267
5.5	199	
5.5		234
5.5		225
5.5	240	
5.5		210
6		270
6		226
6		214

6		231
6		231
6	241	
6		207
6		235
6		262
6		230
6		239
6		239
6		242
6	259	
6.5		243
7		278
7		252
7		213
7		230
7	276	
7		226
7.5		249
7.5	247	
8	285	
8		209
8		250
8		333
8		294
8		254
8		273
8		291
8		274
8		285
8		289
8.5		254
9		301
9		258
9		269
9	307.5	
9		259
9.5		331
10		308
10		312
10	326	
10	341	
10.5		266
11		320.5
11		323
11		329
11	318	
11		294
11		260

11	295	
11		323
11		327
11.5		359
11.5		336
12		282
12		351
12	340	
12		349
12		325
12		352
12		349
12		324
12.5	330	
12.5		351
13		352
13		345
13.5		362
13.5	345	
13.5		291
13.5		359
13.5		333.2
14		391
14	365.2	
14		375
14	372	
14		301
14	334	
14.5		387
15		375.8
15		371
15		347
15		363
15		343
15		329
15	347	
15		439
15		339
15.5		421
15.5		387
15.5		357
15.5		362
16		361
16		343
16		383
16		381
16		345
16		385
16.5		373.2

16.5	358
16.5	364.5

A6.10. Femoral lengths of non-adults with and without cribra orbitalia

Age (yrs)	With cribra orbitalia	Without cribra orbitalia
0.1		73.41
0.2		79.95
0.25		81.96
0.25		88.96
0.25		83.73
0.3		82.8
0.3		85.62
0.3		86.23
0.4		98.74
0.4		100.42
0.4		83.41
0.5		96
0.5		94.27
0.6		100.7
1		138
1.3		144
1.5		137.5
1.5		148
1.5	130	
1.5		146
1.5		150
1.5		121
1.8		161
1.8		165
1.8		135
1.8	165	
1.8		166
1.8		152
2		157
2		159
2.5		118
2.5		161
2.5		200
2.5		190
2.5	176	
2.5		180
2.5		159
2.5		162
2.8		186
3		173.52

3	153	
3	168	
3		178
3.3		222
3.8	198	
4	177	
4		215
4		186
4.3		205
4.5		175
4.8	196	
5		241
5		214
5		199
5		190
5		218
5		223
5	235	
5		198
5.3		240
5.5		224
5.5		199
5.5	225	
5.8		237
5.8		241
5.8		262
5.8	226	
5.8	234	
6		231
6		230
6	207	
6	214	
6.3	231	
6.3	235	
6.5	243	
6.5		230
7		213
7		276
7	252	
7.3		226
7.5		249
7.5		273
8		285
8	333	
8.3		285
8.3		294
8.5	254	
9		301
9		294

9		259
9.5		258
9.5		331
10		282
10		312
10.3		341
10.5		327
10.8	323	
11		320.5
11		260
11	318	
11.3		359
11.3	349	
11.5		336
12		365.2
12		340
12	324	
12.3		345
12.3		325
12.3	349	
12.5		330
13	329	
13.5		345
13.5		362
13.5	359	
13.7	372	
13.8		343
13.8		334
14	301	
14	347	
14.5	387	
14.8	371	
15	358	
15	373.2	
15		375.8
15		343
15.5		421
15.5		362
16.3		383
17		345

A6.11. Femoral lengths in non-adults with and without metabolic disease

Age (yrs)	With metabolic disease	Without metabolic disease
0.5		94.27
0.5	96	
0.6		100.7
0.8		121
1		138
1.3		132
1.3		144
1.3		144
1.5		121
1.5	130	
1.5	137.5	
1.5		146
1.5		148
1.5		150
1.6		148
1.8		135
1.8		152
1.8		161
1.8		165
1.8		165
1.8		166
2		157
2	159	
2.5		118
2.5		159
2.5		161
2.5		162
2.5	176	
2.5		177
2.5		180
2.5		190
2.5		200
2.8		186
3	153	
3		168
3		173.52
3		178
3		192
3		208
3.3		222
3.5		179
3.8		198
3.8		216
4		177
4		186
4		215

4.3		205
4.8		175
4.8		196
5		190
5		198
5		199
5		214
5	218	
5		223
5		235
5		241
5.3		237
5.3		240
5.5		199
5.5		210
5.5		224
5.5		225
5.8		226
5.8		234
5.8		241
5.8		262
6		207
6		214
6		230
6		231
6.3	231	
6.3		235
6.3		239
6.5		230
6.5		243
7		213
7		252
7		259
7		276
7		278
7.3		226
7.5		247
7.5		249
7.5		273
7.8		254
7.8		270
8		209
8		285
8		289
8		333
8.3		285
8.3		294
8.5		254
9		259

9		294
9		301
9.3		258
9.5		331
9.8		308
10		282
10		307.5
10		312
10.3		341
10.5		266
10.5		327
10.8		323
11		260
11		295
11		318
11		320.5
11		329
11.3		349
11.3		359
11.5		336
12		324
12		340
12		365.2
12.3		325
12.3		345
12.3		349
12.3		352
12.5		330
13	329	
13.3		363
13.5		345
13.5		359
13.5		362
13.7		372
13.8		334
13.8		343
14		301
14		339
14		347
14.5		387
14.8		371
15		375.8
15.5	362	
15.5		387
15.5		421
16		343
16		345
16.3		383
16.3		385

A6.12. Femoral diaphyseal lengths from the non-adults at Christ Church Spitalfields

Age (yrs)	Romano-British non-adults	Christ Church Spitalfields non-adults
0.2	79.95	79
0.3	82.8	92
0.3	81.96	84
0.3	88.96	83
0.3	75.07	82
0.3	85.62	87
0.3	83.73	
0.3	86.23	
0.4	98.74	89
0.4	83.41	93
0.4	100.42	71
0.4		91
0.4		83
0.4		122
0.4		112
0.5	94.27	97
0.5	96	94
0.5		91.5
0.5		104
0.6	100.7	104
0.6		116
0.7		104
0.7		111
0.7		111
0.7		122.5
0.8	121	121
0.8		122
0.8		127
0.9		131
0.9		110
1	138	
1.1		124
1.2		122
1.2		122
1.2		144
1.2		158
1.3	132	126
1.3	144	116
1.3	144	143.5
1.4		152
1.4		156
1.4		143
1.4		133
1.4		134
1.4		117
1.4		149

1.5	130	134
1.5	148	164
1.5	137.5	
1.5	150	
1.5	121	
1.5	146	
1.6	148	152
1.7		116
1.8	152	123
1.8	161	
1.8	135	
1.8	165	
1.8	165	
1.8	166	
2	157	134
2	159	
2.1		179
2.3		161
2.5	159	
2.5	118	
2.5	176	
2.5	177	
2.5	190	
2.5	180	
2.5	161	
2.5	200	
2.5	162	
2.7		199
2.7		159
2.7		208
2.7		170
2.7		196
2.7		142
2.8	186	
3	153	
3	168	
3	208	
3	192	
3	178	
3	173.52	
3.2		195
3.3	222	
3.5	179	194
3.5		193
3.5		194
3.8	198	
3.8	216	
3.9		200
3.9		180

4	186	
4	215	
4	177	
4.3	205	
4.5		216
4.8	175	
4.8	196	
5	241	
5	214	
5	198	
5	190	
5	235	
5	199	
5	218	
5	223	
5.1		184
5.2		191
5.3	240	
5.3	237	
5.5	199	207
5.5	225	
5.5	224	
5.5	210	
5.8	226	228
5.8	234	
5.8	241	
5.8	262	
6	214	216
6	231	
6	207	
6	230	
6.1		238
6.3	231	
6.3	235	
6.3	239	
6.5	230	
6.5	243	
6.6		228
6.7		297
6.9		263
6.9		224
7	259	
7	276	
7	252	
7	278	
7	213	
7.3	226	
7.5	249	
7.5	247	

7.5	273	
7.8	270	
7.8	254	
8	289	
8	209	
8	285	
8	333	
8.3	285	
8.3	294	
8.5	254	
9	259	
9	301	
9	294	
9.1		321
9.3	258	
9.5	331	289
9.5		313
9.8	308	321
10	307.5	
10	282	
10	312	
10.3	341	
10.5	327	
10.5	266	
10.8	323	
11	295	
11	320.5	
11	329	
11	318	
11	260	
11.3	359	303
11.3	349	306
11.5	336	360
12	365.2	
12	324	
12	340	
12.3	325	
12.3	345	
12.3	349	
12.3	352	
12.4		365
12.5	330	
12.8		371
13	329	
13.3	363	
13.5	362	
13.5	345	
13.5	359	
13.7	372	

13.8	343	
13.8	334	
14	301	
14	339	
14	347	
14.5	387	
14.8	371	
15	375.8	
15	358	
15	373.2	
15.4		373
15.5	421	
15.5	387	
15.5	362	
16	345	
16	343	
16.3	383	
16.3	385	

APPENDIX VII

COMPARATIVE DATA

A7.1. Crude prevalence rates of skeletal lesions in Romano-British non-adults for comparison with Redfern (2007)

	Cribra orbitalia		**Enamel hypoplasia**		**New bone formation**		**Trauma**	
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*
0-2.5 years								
Major urban (N=107)	4	3.7	6	5.6	2	1.9	2	1.9
Minor urban (N=133)	6	4.5	7	5.3	0	0	2	1.5
Rural (N=90)	10	11.1	0	0	2	2.2	1	1.1
2.6-6.5 years								
Major urban (N=62)	10	16.1	11	17.7	4	6.5	0	0
Minor urban (N=68)	19	27.9	12	17.6	2	2.9	0	0
Rural (N=32)	6	18.8	1	3.1	1	3.1	1	3.1
6.6-17.0 years								
Major urban (N=120)	21	17.5	37	30.8	9	7.5	4	3.3
Minor urban (N=70)	15	21.4	24	34.3	2	2.9	5	7.1
Rural (N=46)	12	26.1	11	23.9	3	6.5	2	4.3

% of cohort by site type

A7.2. Crude prevalence rates for caries and rickets in Romano-British non-adults for comparison with Redfern et al. (2012)

	Rickets			**Caries**		
	n	*%*	*N*	*n*	*%*	*N*
0-2.5 years						
Major urban	7	6.5	107	1	1.4	74
Minor urban	10	7.5	133	0	0	90
Rural	6	6.7	90	0	0	48
2.6-10.5 years						
Major urban	1	0.9	106	15	17.4	86
Minor urban	2	2	98	9	10.7	84
Rural	0	0	43	0	0	30
10.6-17.0 years						
Major urban	1	1.3	76	12	17.9	67
Minor urban	0	0	40	9	27.3	33
Rural	0	0	35	3	11.1	27

% of cohort by site type

A7.3. Crude prevalence rates for non-adult palaeopathology in Late Iron Age Dorset

Type of lesion	**Infant 0-3 years**	**Child 3-7 years**	**Juvenile 8-16 years**	**Adolescent 17-20 years**
Cribra orbitalia	0	1.0%	2.0%	0
Enamel hypoplasia	1.0%	0	4.0%	1.0%
Periosteal new bone formation	0	0	5.0%	1.0%

(from Redfern 2007)

A7.4. Crude prevalence rates for non-adult caries and rickets in Late Iron Age Dorset

Type of lesion	**Infant 0-3 years**	**Child 3-12 years**	**Adolescent 12-20 years**
Rickets	11.1%	0	0
Caries	0	16.7%	40.0%

(from Redfern et al. 2012)

A7.5. Prevalence rates of skeletal lesions in the Christ Church, Spitalfields non-adults

	Cribra orbitalia			Enamel hypoplasia			New bone formation		
Age (years)	*n*	*%*	*N*[1]	*n*	*%*	*N*[2]	*n*	*%*	*N*[3]
0-0.5	6	35.3	17	0	0	4	0	0	35
0.6-2.5	29	53.7	54	10	20.0	50	2	2.9	69
2.6-6.5	17	73.9	23	3	15.0	20	2	9.1	22
6.6-10.5	8	66.7	12	6	54.5	11	1	9.1	11
10.6-14.5	3	100	3	2	66.7	3	1	16.7	6
14.6-17.0	0	0	2	1	33.3	3	0	0	4
Total	**63**	**56.8**	**111**	**22**	**24.2**	**91**	**6**	**4.1**	**147**

(from Lewis 2002c; [1]individuals with orbits; [2]individuals with dentition; [3]individuals with tibiae; % of cohort by age group)

A7.6. Crude prevalence rates of metabolic disease in the Christ Church, Spitalfields non-adults

	Rickets			Rickets/scurvy			Total metabolic disease		
Age (years)	*n*	*%*	*N*	*n*	*%*	*N*	*n*	*%*	*N*
0-0.5	3	7.5	40	4	10	40	7	17.5	40
0.6-2.5	14	17.1	82	4	4.9	82	18	21.9	82
2.6-6.5	0	0	24	1	4.2	24	1	4.2	24
6.6-10.5	1	8.3	12	0	0	12	1	8.3	12
10.6-14.5	0	0	6	0	0	6	0	0	6
14.6-17.0	0	0	6	0	0	6	0	0	6
Total	**18**	**10.6**	**170**	**9**	**5.3**	**170**	**27**	**15.9**	**170**

(from Lewis 2002b, 86; 2002c; % of cohort by age group)

A7.7. Prevalence rates of skeletal lesions in 0.6-2.5 year olds from Roman Britain

	Major urban			**Minor urban**			**Rural**		
	n	*%*	*N*	*n*	*%*	*N*	*n*	*%*	*N*
Cribra orbitalia[1]	4	12.1	33	6	12.8	47	9	50.0	18
Enamel hypoplasia[2]	6	14.3	42	7	11.3	62	0	0	30
New bone formation[3]	2	6.3	32	3	3.9	76	0	0	33
Rickets	4	8.7	46	3	3.6	84	4	10.3	39
Rickets/scurvy	0	0	46	1	1.2	84	1	2.6	39
Total metabolic disease	**4**	**8.7**	**46**	**5**	**5.9**	**84**	**8**	**20.5**	**39**

([1]N=individuals with orbits; [2]N=individuals with anterior dentition; [3]individuals with postcrania; % of cohort by site type)