Intrinsic and Extrinsic Factors Involved in the Preservation of Non-Adult Skeletal Remains in Archaeology and Forensic Science

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Abstract
Human skeletal remains offers the most direct insight into the health, well-being, and the lifestyles of both past and modern populations, as well as the study of violence and traumas encountered both from archaeological and forensic contexts. They also allow archaeologists and anthropologists to reconstruction demographic details, none more so than those of children, where mortality rates were high in most human populations until the twentieth century. The study of children within biological anthropology had being taking place for many years now, but studies of mortality and morbidity are often hindered by the poor preservation of their skeletons or infrequent representation of skeletal elements. Taphonomic processes are often cited as the cause of this 'under-representation' of children from archaeological investigations. This phenomenon is thought to be as a result of the inability of non-adult bone to survive the changing conditions of the burial environment in which they are interred. Taphonomic factors can be divided into two types: intrinsic (resistance to bone) and extrinsic (environmental influences), both of which exert influence on the long term survival of non-adult bone. This paper aims to review the many intrinsic and extrinsic factors which can alter human bone and contribute to its deterioration in the burial environment in both archaeology and forensic science.

Keywords: Forensic; Bioarchaeology; Taphonomy; Children; Skeletal Remains

Introduction

Taphonomy is a term deriving from the Greek words 'taphos' (burial) and 'nomos' (laws), and was first coined by Efremov in the 1940s (1). Efremov defined taphonomy as being the study of the '*transition of all its detail of animal remains from the biosphere to the lithosphere or the geological record'.* Taphonomy was originally a palaeotological term, but today, has been adopted by a range of experts, such as, zooarchaeologists, archaeologists and forensic scientists as a means to explain the many processes involved in the decomposition and skeletonization of human and animal burials. Efremov (1) implied that all processes affecting an assemblage (s) prior to its incorporation into a stable sub-soil should be termed 'taphonomic'. This could include both diagenesis and a range of anthropogenic processes such as selective killing, cooking and disposal practices. It can be argued that the main agent responsible for the outcome of human assemblages is humans themselves and how they treat their dead (2).

Numerous authors have defined taphonomy in different ways. Bonnichsen (3) proposed the meaning of taphonomy as '*the study of the accumulation and modification of osteological assemblages from a formation perspective'.* Alternatively, Olsen (4) defined taphonomy '*as the reconstructing of history of a fossil from the time of death to the time of recovery'.* A more exclusive definition was used by Millard and Hedges (5) who described taphonomy as being distinct from both anthropogenic processes and diagenesis. According to Millard and Hedges the main taphonomic processes include digestion, trampling, burning and weathering.

The state of preservation and representation of human remains can be determined by taphonomic factors, which may in turn be related to funerary practices, grave types, excavation and storage. Since the 1950s, the focus has been on the fossil record in terms of how well it reflects the actual palaeoecology of the biotic community (6), and on the selective processes that determine the contribution of a fossil assemblage (7). Many authors have contributed to the study of biological and cultural activity in past populations (8-13) and in more recent years the focus has shifted to archaeological and forensic anthropology (14-15).

The survival of human bone is dependent on many variables, such as, soil pH, soil type, bone type and size, age and sex of the individuals. There is often an under-representation of children's skeletons recovered from archaeological sites (16-19). This phenomenon is thought to be as a result of the inability of non-adult bone to survive the changing conditions of the burial environment in which they are interred. This paper aims to review the many intrinsic and extrinsic factors involved in bone preservation and how they relate to the skeletons of children.

INTRINSIC FACTORS INVOLVED IN THE PRESERVATION OF BONE

Age

Age is important in relation to bone size. The bones of children are both smaller and less dense than adult bone; therefore they undergo decomposition processes in a shorter time than adults. Children's bones have a high organic and low inorganic content which, in theory, makes them more susceptible to decay (20). However, there is a lack of studies on the chemical makeup of non-adult bones to draw any firm conclusions. Guy et al. (20) stated that *infant type remains are soft, ill-structured bones, rich in interstitial water, and poorly protected from chemical and mechanical degradation*. In addition, child remains are easier to disarticulate and remove by animals; this can hamper any investigation or excavation (Figure 1) (21-23). Immature bones are easily dispersed, lost and destroyed compared to adult bones (Figure 2). In a recent study by Manifold (24) on British skeletal assemblages, a preservation pattern was observed in what bones are likely to be present.

Bone type and size

There is a variation in the preservation of different bones. The bones most vulnerable to destruction are thought to be those with a high proportion of cancellous material, such as the sternum, vertebrae, ribs, and epiphyses. Among the vertebrae, it has been thought that the lumbar are the least and the cervical the most affected by soil erosion (25). However, recent studies on large numbers of non-adult skeletons has found this to be in reverse, with the cervical and thoracic vertebrae in abundance, whilst the lumber is poorly preserved or absent (24). This may also depend on the position of the body during burial, and if grave intercutting occurred. According to Mays (25), the hyoid bone and small bones of the hands and feet are almost always poorly represented. Elements with a high proportion of cortical bone, such as the skull, mandible and the long bones appear less affected by preservation (25). Von Endt and Ortner (26) have shown that rates of decay are inversely proportional to the bone size. They found when bones of different sizes were kept in water at constant temperature; nitrogen is released at a rate which is inversely proportional to bone size. Any weakening of the protein-mineral bonding of bone will enhance its degradation. Groundwater and its dissolved ions can penetrate bone, and bone size, both the external and internal surface area (porosity), available to groundwater is important in bone breakdown (26).

Waldron (21) demonstrated that, the dense long bones and the compact parts of the cranium were present in 40-50% of cases, but he also found ribs to be well preserved. Around 60-70% of cases included the vertebrae. Bones which were least preserved included many of the small bones, such as carpals and the phalanges. The body of the scapula was also poorly preserved, possibly due to been thin and vulnerable to damage. This study indicates better preservation of the large dense parts of the skeleton, such as the long bones and the cranium. Finally, Waldron (21) pointed out that the pattern of preservation found in his study is not necessarily the same for other sites. This would suggest that the type of soil and burial environment conditions play an increasingly important role.

Bello et al. (27) analysed four osteological samples, namely St Maximin, St Estève, and Observance, in France; and Spitalfields, in London. In all four samples, the scapulae, sterna, vertebrae, sacra, patellae and hand and foot bones were the least represented in both adults and non-adults. Overall, adult remains appear to survive better than those of non-adults. It was also found that male skeletons were better preserved than female (27). This suggests that bone density of certain bones is lower and therefore, may not survive the burial environment. Absence of the small bones such as the phalanges and carpals not being present maybe also due to excavation (i.e missed or not identified in the laboratory). The non-adult bones examined by Ingvarsson-Sundström (28) from Asine, Greece were found to be in good preservational condition. The bones most frequently found in a complete state were the bones of the hands, feet and vertebrae (arches). Parts of the cranium (the temporal bone: pars petrosa, and zygomatic) were also completely preserved. The findings were similar to Waldron's (21) study West Tenter Street, London except for the phalanges, which were often found complete in the Asine material. In skeletal reports, it needs to be made clear as to what is meant by 'poor' bone preservation. Is this due to the condition of the bones of the skeletons or is it referred to the representation of the various elements. As bones can be recovered in a state of poor preservation (i.e the condition of the surface of the bones), but be well-represented.

Pathology

Pathological conditions and injuries are known to speed up the decomposition of buried bone. When bone is damaged through trauma or as a result of illness, it is easier for micro-organisms to enter; also the same may be said of those individuals with infectious diseases and blood poisoning. When there is a breakdown of bone in life such as with metabolic disease, this can have an effect on the rate of preservation (29-30). Rickets is caused by vitamin D deficiency in children, prevents calcium from being deposited in the developing cartilage as well as in the newly formed osteoid, which impedes bone mineralisation. The macroscopic appearance of rickets in non-adults tends to be long bone bending deformities and metaphyseal swelling. However, in cases of active rickets there is increased porosity of bone surfaces in particular the cranium and the growth plates. This increased porosity can lead to the bone appearing to 'dissolve' in the burial environment, which can make recovery of remains difficult. Another metabolic disease which cannot be frequently diagnosed is scurvy, a condition caused by the lack of vitamin C in the diet. This condition can also lead to an increase in porosity of the non-adult skeleton which makes it vulnerable to the changes of the burial environment (Figure 3). Metabolic conditions such as these, cause a decrease in the mineralisation of non-adult bone, this lack of mineralisation can be misinterpreted as poor preservation rather than disease (31).

Porosity and bone density

Porosity has become an important indicator for diagenetic changes in bone. There is an increase in porosity as a result of mineral dissolution. Chaplin (32) noted that the rate of dissolution is dependent on the porosity of the skeletal tissue, as more porous tissues decays more rapidly than less porous tissue. This is important for non-adult bone as it has been shown that non-adult remains are more susceptibility to diagenetic contamination (26, 33-34) and this can be from the surrounding soil. More recently, Wittmers et al. (35) reported very high levels of diagenetic lead in the remains of newborns and young children, which they attributed to the increased porosity of such remains. Computer tomography (CT) images of non-adult bone have shown this to be the case in bones from a chalk environment where carbonate was absorbed from the soil (Manifold, unpublished). Armour-Chelu and Andrews (36) found that a chalk environment was not favourable for bone preservation at Overton Down in the UK, where surface modification of non-adult remains occur within a few years due to their porous nature (Figure 4). The pore structure, which can be defined as the distribution of porosity for a given pore radius, can influence the amount of diagenesis. An increase in the rate of mineral dissolution process, will lead to greater porosity (37). Hedges and Millard (38) have highlighted pore structure as being of central importance when modelling bone mineral loss. Pore structure governs the internal surface area which is available for solid solution reactions. It also determines the rate at which groundwater can flow through the bone, and the rate at which diffusion can take place. Pore size also determines which pores will be filled with water and which will be empty, and so controls which parts of bones will interact with soil water. Numerous authors have put forward suggestions that bone porosity is important in the predicting the extent diagenesis (29, 38-39, 40). Lyman (13) indicated that 46% of the 184 assemblages studied were significantly and positively, correlated with bone density. It is thought that those processes that affect archaeological bones, do not affect modern bone. Nicholson (40) identified bone density as an important variable, but stressed that bone size was also of importance and that '*it is unclear at what point bone size becomes more important than bone density….in influencing bone loss'.*

EXTRINSIC FACTORS INVOLVED IN THE PRESERVATION OF BONE

Groundwater

It is believed that groundwater is the most influential agent of bone diagenesis (37). Hedges and Millard (38) defined three hydrological environments: diffusive, recharge and flow. The diffusive regime refers to an environment where water movement is limited, in waterlogged conditions or where soils are not permanently saturated. With a recharge regime bones go through wetting and drying cycles, and as a result, porosity increases and the formation of large pores which increases the affects of the water cycle. Finally, in the flow regime the presence of bone buried in such an environment tends to depends on the volume of water, (i.e rainfall and seasonal factors) (38). Groundwater is the medium for all other processes such as recrystallisation, dissolution, hydrolysis, microbiological attack and ion exchange to take place (37). In general, bone buried in soil where water movement is limited and calcium and phosphorous concentration are high, has the potential to survive for an indefinite period. Where water movement is greater there tends to be greater dissolution, and therefore, less well-preserved bones, both macroscopically and microscopically (41).

Soil type and pH

Unfavourable geological conditions are often cited as a cause of poor preservation, but how much influence this has on sites and skeletal remains in Britain remains unclear. The geology of Great Britain is complex, with varying types and amounts of soil in each region. Soil type can be broken down into around 13 groups (Table 1). Therefore, preservation of bone varies considerably, not only from soil to soil, but also from one place of burial to another. Soil is made up of mineral and organic matter, air, water with differing soil types composed of differing ratios. Soil can be classified according to particle size as, clay, silt, sand or gravel (42) and soil pH is determined by the amount of hydrogen ions present. The concentration of which can be classed as neutral, acidic or alkaline (43). Environments affect bone in different ways (Table 2). In acidic environments, which can consist mostly of podsols, these soils tend to be abundant in Northern England and Scotland, where there is a tendency for the soils to be thin, acidic and wet, which may or may not have a negative impact on bone preservation (44). On the other hand, many peat environments have revealed excellent preservation due to the acidic nature of the sites in such an environment there is a lack of microbial attack and an accumulation of organic matter, which leads to the formation of blanket bog (45). In a more alkaline environment, which consists of calcareous soils can result in mixed preservation, if remains are recovered from this soil type and have a high pH, then they tend to be in good condition (45), these soils tend to be found in the East Anglia and eastern and south-west England. In soils of a neutral pH, there can be varied conditions, these soils are well-drained and mostly located on the gravel and chalk areas of southern England. An increase in biological activity leads to a breakdown of organic matter, which results in a well-mixed, aerated soil and can lead to poor bone preservation (45).

The main constituents of bone; the organic part (collagen) and mineral part (hydroxyapatite), are preserved at opposing pH levels (46). It is generally known that soils with a neutral or alkaline pH are better for preservation of bone, rather than acidic soils (29, 44), but this is not always the case. Locock et al. (47) found, that soil pH was not said to be the main controlling factor in the preservation of buried bone (47). Some demineralisation of bone may occur as a result of the action of organic acids released during decomposition of the soft tissues, and therefore present in the soil where the bones are exposed (48). Overall, it would appear that the literature has produced come contradictions as to what environment is best for bone preservation. Henderson (29) stated that the speed of decomposition is increased in light porous soils, whilst dense clay soils may decrease the rate of decomposition, and the deeper the burial, the poorer the preservation due to waterlogged clay (29). However, there may be limitations to these studies using animal bones, which may react differently to those of the human skeletons to soil conditions. Nicholas (40) found acid moorland (pH 3.5-4.5) was the most destructive to bone and a chalk environment (pH 7.5-8.9) was the most favourable. However, between these two sets of figures there are many variables and should be used as an indication of the extremes. Maat (49) reported that the role of soils in preservation may be overestimated. This should be viewed with caution, as a more recent study based on the decomposition of juvenile rats has shown that microbial activity is a major contributor to cadaver decomposition in soil, and it also shows that the persistence of a cadaver in soil can be influenced by the surrounding temperature and soil type (50). This would make soil pH and soil type a major determinant of bone preservation, and most probably in the less dense bones of non-adults. Other factors such as the depth of burial and type of burial should be considered alongside pH. In study by Nord et al. (51) on the degradation of archaeological objects and bones from prehistoric graves in Sweden, it was found that the environment affects preservation in three ways; firstly, the chemical environment (soil acidity) mainly affects the macroscopic appearance of the bone, secondly, the microbial activity, composed mainly of bacteria and fungi have a destructive affect on the organic contents of bone and the histological structure. Thirdly, the inorganic material is mainly destroyed by soil acidity, whereas proteins degrade at a higher pH. It would appear that calcareous soil is most suitable for the good preservation of macroscopic structure of human bone (52).

Hydroxyapatite is relatively insoluble at pH 7.5, but is very soluble below pH 6, an example of very acidic soils is Sutton Hoo, Suffolk where no bones survived except soil stains (47). Soil pH in relation to age has proven to have an effect on the preservation of non-adults bones, which tend to decline more rapidly with increasing soil acidity. Mays (52) has reported good preservation in 60% of the infants recovered at Wharram Percy, and relates this to the alkaline burial environment, which has a pH of 7.3-8.5. Gordon and Buikstra (53) found that bone preservation was correlated with age of death, with younger individuals tending to have poorly preserved bones. It was found that at *'marginal pH ranges all or most of the infants and children may be systematically eliminated from the mortuary samples by preservational bias'* (53). Walker et al. (54) examined skeletal remains recovered from Mission La Purisima, California and noted that poorly calcified remains of children were more susceptible to decay, which was due to the acidic soil in which they were buried, which allowed water to permeate through the bone, with subsequent soaking and drying distintegrating the fragile ribs and spine. The burial records for Mission La Purisima indicating 32% of the individuals buried in the cemetery were under 18 years, but only 6% of the skeletons represented individuals of this age. Nielsen-Marsh et al. (55) and Smith et al. (56) found that two categories of bones exist; those where preservation is determined by soil chemistry and those determined by taphonomy. In these studies, soil was classes into two groups, corrosive and benign. The corrosive soils were characterised by a low pH, high exchangeable acidity, and low organic content. These soils were mostly found in north and Western Europe, and are dominated by free-draining soil, (i.e sand and gravel and associated with absence of calcareous bedrock). In contrast, the benign soils had a more neutral pH value, low exchangeable acidity and a high organic content. It was found that 'benign' soils did not have a big influence in determining preservation (55). Smith et al. (56) found that the state of preservation of bone did not appear to be related to soil conditions of a particular site, but to the taphonomic history before burial. Post-mortem defects also occur and must be taken into account when interpreting remains. Defects due to soils chemical erosion, exposure to the sun, water and mechanical processes can be observed on various parts of the skeletons (57). Soil activity is the primary cause of bone changes; soil chemical erosion causes proteins to be demineralised by acid environment and decomposition of bone occur due to bacteria. As a result, bones can become lighter and totally degrade; but whether this occurs in the remains of children is still debatable (57).

Temperature

Temperature and its affects vary with latitude, season, and depth of burial (29). One general rule is the reaction rate, which is approximately double for every 10℃ rise in temperature (47). Temperature can have a profound effect on the chemical and biological processes in the soil (58), any increase in temperature will increase the activity of insects and bacteria, whereas any decreases in temperature will lead to the formation of ice crystals and the destruction of cell structure, the propagation of microfractures of bone, and disruption of the natural soil layer (59). These influctuations in soil temperature at a burial site can influence the survival of human remains (58). It has been found that decay of organic components were faster at higher temperatures. Temperature variation can cause expansion and contraction of the earth, which can cause fragmentation of bone. This appears to be a particular concern when the bones are those of infants and children (28). These changes were observed at the Anglo-Saxon cemetery of Raunds Furnells, where 70% of the neonates and 10% of adolescents were fragmented, which was thought to be caused by the expansions and contraction of the Blisworth clay (60). More recently, it is reported that shallow burials of depths less than one metre would be expected to be more affected by soil temperature than those buried at depths of more than one metre (59). Crist et al. (61) described the process of bone displacement in non-adult crania from forensic contexts. The observed alternations were found to be inconsistent with lesions expected as a result of antemortem or perimortem trauma. It was suggested that the lesions were caused by taphonomic processes, like postmortem warping. This is important in establishing cause of death.

Flora and fauna

Flora and fauna plays a part in preservation, either directly or indirectly. Direct attacks on bone can result in damage and destruction of bone tissue; whereas indirect attacks result in disturbance of the remains and can lead to their removal and scattering of bones which can make collection difficult (29). Fauna can be responsible for disturbances and breakage of bone. Insects are known to destroy human remains, their influence varies with conditions of burial and factors such as season, latitude and altitude (62). They can cause destruction of small bones and teeth. Also snails and other mammals can prey on human remains, destroying bones by gnawing, thus causing damage which can lead to alternations suggestive of pathology (29).

Plant roots

Plant roots can also damage bone; the marks can resemble pathological conditions and thus, cause misinterpretation of disease (63). Large roots leave indentations on the surface of bones and often the roots grow through the bones leaving holes which can be misinterpreted as ante mortem injuries, such as cancers and trepanations or injuries from arrows. Roots of plants growing around and above burials can cause both physical and chemical degradation. Roots creep into bones and exert a strong pressure on the bone walls, eventually causing fragmentation. They can also cause the dissolution of mineral components of bones by excreting humic acids. Lyman (13) described ‘root etching’ which results in erosion of the cortical surface and can lead to complete dissolution of bones over time (Figure 5).

Human impact

The human impact on preservation is important. The obvious one is treatment of the body after death, type of burial-inhumation or cremation (29). Depending on how the corpse was treated prior to burial. In cremation, the bones are left in a friable state due to the disappearance of the organic components. This, however, may depend on the length of cremation, temperature, amount of fat and body position (28). With regard to the burial remains, the presence of coffins of wood, stone, or lead may protect bones from the surrounding environment. However, coffins made of wood collapse and decay over time, and can retain percolating water, which can subsequently cause bone destruction. Lead from coffins can leach into bones preventing examination of pathology on radiographs. Also, human impact can affect primary and secondary burials. Secondary burials may be confused with disturbance when based on the lack of completeness of the burials (2). Often secondary burials have an abundance of certain bones such as the skull and lack of other bones such as tiny bones of the hands and feet. When a body is moved from its primary burial site to a secondary site, some bones particularly small and distal elements can be lost during transfer. This can be the case with infant and child bones (2).

Finally, the role of excavators and archaeologists may contribute to what bone elements are recovered and what is not. This may be due to the recognizing of bone elements, especially the developing epiphyses of the long bones, which are small pebble-like and easily mistaken for small stones.

Grave depths

There is a common perception in archaeology that non-adult graves are shallow or pit graves, which are easily, exposed resulting in poor bone preservation or plough damage. Bello et al. (27) found that the non-adult graves at St Esteve Le Pont cemetery, ranged in depth from 0.1 to 0.3 metres, whereas the adult graves ranged from 0.1 to 1.4 metres deep. They suggested that two funerary patterns existed, with deeper graves for the adults and shallower graves for the non-adults (27). This also appeared to be the case at the Roman cemetery of Cannington, Somerset; where the infants had a greater tendency towards shallow graves, whereas the graves of the older children were similar in depth to the adults (64). The depths and lengths of children's graves are not always recorded, especially in the older collection excavations. Nevertheless, Ingvarsson-Sundstrom (28) reported that the graves of children in the lower town of Asine were shallow pit graves, which were often overlooked during excavation. At the fifth century rural cemetery of Chantambre in France, Murail and Girard (65) showed that children less than 15 years of age were buried at 1.40m compared to 1.56m for the adults and older children. Murail et al. (66) reported that a large number of children's graves at the classic Kerma cemetery in Sudan were shallow, ranging from a few centimetres up to 30cms. At the Anglo-Saxon site of Castledyke South, Barton-on-Humber, non-adult graves ranged in depth from 0.05m up to 0.40m but there was no age correlation to grave depths as some of the older children were buried at a very shallow depth compared to a neonate who was buried at 0.30m (67). At the Anglo-Saxon cemeteries of Beckford and Worcester, non-adult burial ranged in depth from 0.6-0.7m to 1.2-1.2m, again no distinct burial and age pattern, as some of the adults' burials were shallower than the non-adults (68). At the multi-period site of St Peter's, Barton-upon-Humbar; the children were rarely buried at greater than 0.6m. Whereas the adults ranged from 1.2m to 1.5 m inside the church, and outside the church a depth of around 0.5-0.7m (69). At the Roman site of Poundbury Camp in Dorset, variety of depths were recorded, with the shallowest non-adult burials belonging to the late Iron Age/ early Roman burials which were buried at 0.23m and the late Roman burials at 0.25m. This difference in burial depth across a cemetery may give indicators of the status of the individuals interred there, but may also be due to practical issues and differences in the burial matrix. Panhuysen (70) found no differences in depths of graves at cemeteries in Maastricht, The Netherlands. Sellevold (71) found that the length of the grave did not correspond with the age of child and graves for newborns did not vary in size or length. Acsádi and Nemeskéri (17) also reported no differences in grave depths between adults and non-adults from a selection of Hungarian sites.

Shallow burials make detection and disturbance by scavengers' easier (72). In cases of scavenging by animals it is often the small bones that are disturbed, and the spongy, marrow rich bone that is preferred for gnawing (73). Morton and Lord (23) found that child sized remains were removed from a shallow burial within the first week of burial and scattered over a significant area. They also reported that remains interred in shallow graves/burials were subjected to greater scattering than those that decomposed on the surface. This indicates that those bodies buried just below the surface are more prone to destruction and scattering than those in deeper burials. Shallow burial also makes the skeleton more susceptibility to plough damage (Figure 6). Scull (74) observed at Watchfield cemetery in Oxfordshire that infants and young children were interred in shallow graves and those burials recovered were within or at the base of the ploughsoil. In a recent study by Manifold (unpublished), on the grave depths of non-adult and adult burials from a number of Roman and early medieval cemeteries were recorded and the age of the non-adult was explored to see if there was difference in the type of burial the received. It was found that those non-adults in the 0-1 year age category were consistently buried at less depth than the older children and adults (Figure 7). Overall, it was found that the non-adults were buried at less depth than the adults (Figure 8). In the Roman period, there does appear to be differences in the grave depths of non-adults in this age category. It is seen consistently through both periods. In the Roman period, the average depth for the 0-1 year group is 32cms, whereas for the 1-4 years group the average depth is 38cms. A further increase in depth is seen in the 5-10 years age category with an average depth of 43cms. In the older age category of 11-17 years, an average of 39cms. In contrast to the average adult burial depth of the Roman period which is 57cms and for the non-adults 34cms. Similar results were obtained for the Anglo-Saxon period with the 0-1 year age category having an average depth of 35cms and the older age groups having an increasing depth with an average of 40 cm for the 1-4 years, 42cm for the 5-10 years and 45cm for the 11-17 years. The overall average for the Anglo-Saxon period for the non-adults is 43cm and for the adults 49cm (Manifold, unpublished). This may reflect the age of the child and the size of the child, rather than lack of care. With regard to the depths of burials in the medieval periods onwards, they appear to vary considerable and cannot be predicted with confidence; also in many large urban cemeteries intercutting of graves have occurred, so it is difficult to assign a depth to the original grave. As children appear to be buried at similar depths to those of adults, it may indicate a difference in views towards the acceptance of children as full members of the community.

Conclusions

The evidence from the taphonomy literature does suggest that infant and children's remains do decompose, and that smaller bones, with higher collagen and lower density are more prone to decay more rapidly than their adult counterparts. The literature also suggests that non-adults remains have the potential to be well-preserved, despite the many factors involved in their decay. Preservation is just one of several reasons why a lack of infants and child remains exist in the burial environment. Burial practice and excavation techniques need to be considered also. There appear to be a distinction in the grave depth between adults and children. Shallow graves can makes non-adult burials more prone to damage. With non-adults now been given more consideration at excavations, and as more sites are published, a true picture of 'under-representation' should emerge.

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Soil group	Where found
Alluvial soils	Lincolnshire, Kent and Norfolk
Coastal sandy regosols	Highlands, Moray, Aberdeenshire, Lincolnshire, Norfolk, Lancashire and Cumbria
Rendzinas or calcaric brown soils, with associated luvic brown soils	Hampshire, Wiltshire, Gloucestershire, Yorkshire, and North Lincolnshire
Brown soils, mainly sandy, with associated rendzinas, podzols or gley soils	Norfolk and Suffolk
Brown soils, mainly orthic or prodzolic, with gley soils and rankers	Aberdeenshire, Fife, Angus, Cornwall, Devon, Pembrokeshire, Ceredigion and Powys
Brown soils, mainly luvic with gley soils	Kent, Herefordshire, Hertfordshire, Devon, Bath and Glamorgan
Podzols with brown and gley soils	Dorset, Surrey
Non-hydromorphic Podzols and podzolic brown soils, with stahnopodzols and gley soils	Cornwall, Devon, Highlands, Moray, Aberdeenshire
Oro-artic podzols, rankers and lithosols with gley and peat soils	Highlands, Perth and Stirling
Pelo-calcaric brown or pelocalcaric gley soils, with associated brown and gley soils	Essex, Cambridgeshire, Northamptonshire, Lincolnshire, Dorset, Wiltshire and Oxfordshire
Gley soils, mainly orthic or luvic with brown soils	Norfolk, Sussex, Surrey, Kent, Devon, Leicestershire. Powys, Shropshire, Cheshire, Lancashire, Yorkshire, Northumberland, Lothian and Ayreshire.
Lowland peat bogs (fens and raised) with humic gley soils	North Lincolnshire, Cambridgeshire
Bog soils (blanket)	Highlands, Dumfries ad Galloway, Scottish borders, Northumberland, Cumbria, Conwy, Gwynedd, Devon and Yorkshire

Table 1 Soil type and location in the United Kingdom, adapted from the soil atlas of Europe (75)

DEPOSITIONAL ENVIRONMENT	MAIN SOIL AND SEDIMENT TYPE	TYPICAL LOCATIONS	COMMENTS
Acid, pH <5.5, oxic	Podsols and other leaching soils	Heathland, uplands moors, some river gravels	Soils are fully aerated; develop on nutrients-poor and freely-draining parent materials. Organic materials not normally preserved (i.e bone)
Basic, pH >7.0. oxic	Rendsinas, lake marls, tufa, alluvium, shell sand	Chalk and limestone areas, valley bottoms	Soils are calcareous in nature. Good preservation of organic material, with possible eroded surfaces
Neutral, pH 5.5-7.0, aerobic	Brownearths and gleys, river gravels	Clay vales and other lowland plains	This type of soil is prone to waterlogging. Organic materials can be poorly preserved
Acid or basic, anoxic	Peats and organic deposits	Urban sites, wetlands, river floodplains	Varied conditions. Most kinds of biological materials are preserved

Table 2 Preservation environments with reference to pH, adapted from Evans and O'Connor (76)

Figure 1 The fragmentary remains of a non-adult skeleton from the site of Auldhame, Scotland (Photo: Bernadette Manifold)

Figure 2 Well preserved non-adult skeleton from the site of Great Chesterford, Cambridgeshire (Photo: Bernadette Manifold)

Figure 3 Example of metabolic disease on the ribs of a non-adult from the site of Wharram Percy, Yorkshire (Photo: Bernadette Manifold)

Figure 4 Example of a skeleton interred in a chalk environment from the site of Bishopstone, Sussex (Photo: Bernadette Manifold)

Figure 5 Example of plough cuts on the vertebrae of a non-adult skeleton from the site of Auldhame, Scotland (Photo: Bernadette Manifold)

Figure 6 Example of root etching on the skull of a non-adult from the site of Great Chesterford, Cambridgeshire (Photo: Bernadette Manifold)

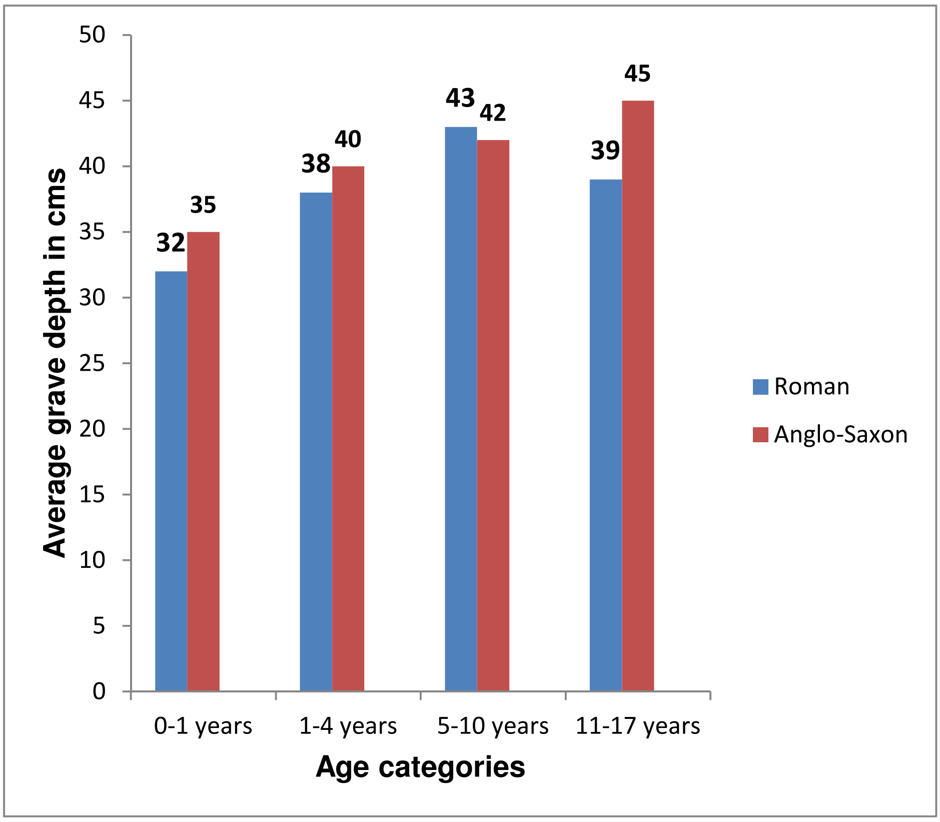

Figure 7 Age and burial depth of Roman and Anglo-Saxon burials

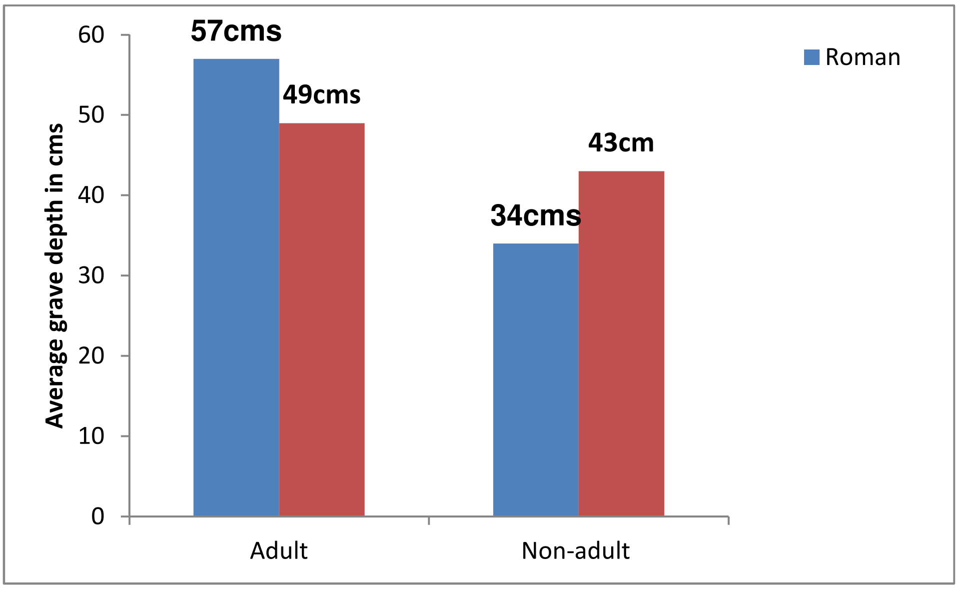

Figure 8 Adult and non-adult grave depths