fresh foods are available other factors may restrict access to them. Occupation may prevent consumption of fresh foods, for example sailors who had a high risk of developing scurvy during long sea voyages. Cultural behaviour can result in vitamin C deficiency if certain foods are avoided altogether, or socially defined groups are forbidden them, and cooking food destroys a large percentage of the vitamin C it contains (Aufderheide and Rodríguez-Martín 1998). General food shortages can also result in inadequate vitamin C intake, so poverty, famine, wars or natural disasters can also place individuals or populations at risk of developing scurvy.

If the consumption of vitamin C stops completely, then it takes 1-3 months for the first symptoms to appear (Aufderheide and Rodríguez-Martín 1998). Vitamin C is needed to produce collagen, and without the collagen small blood vessels are weakened and become vulnerable to damage. This leads to haemorrhages, which appear as dark bruises beneath the skin; deeper haemorrhages can compress nerves leading to paralysis, and veins, leading to thrombosis. Bleeding into the orbital roof (above the eyes) can result in the eyeball being pushed forward; the gums become infected, the teeth loosen and eventually are lost altogether; old wounds can re-open as the collagen in the scar tissue dissolves; and internal bleeding can affect the brain, heart and lungs (Aufderheide and Rodríguez-Martín 1998; Ortner 2003). Scurvy has a high mortality rate: 23,000 French soldiers died of scurvy in the Crimea in 1854 (Aufderheide and Rodríguez-Martín 1998, 312).

Children and infants are more susceptible to vitamin C deficiency than are adults. In addition to the risk of haemorrhage, the lack of collagen prevents normal growth of the bones, so growth is retarded and the bones are vulnerable to fractures (Ortner 2003; Aufderheide and Rodríguez-Martín 1998). The skeletal changes associated with scurvy are usually most severe in infants. These include new bone formation in the orbits, various parts of the skull, long bones and sternal ribs; as well as expanded metaphyses (the ends of the long bones), fractures, and thinner bone cortex (Ortner 2003; Aufderheide and Rodríguez-Martín 1998).

Plate 1 Orbits of SK218 with new bone formation

Three of the non-adult skeletons at Kirby Grindalythe showed skeletal changes that possibly indicate they had suffered from scurvy. Skeleton 218 (6-12 months) had an extensive 2-3mm thick layer of porous brown woven bone occupying the whole of the anterior and middle sections of both orbits (Plate 1). The left orbit had broken post-mortem allowing observation of the intact original bone surface beneath the proliferation of new bone. Thin, grey, porous new bone was seen on the majority of the endocranial (inner) surface of the skull: on the frontal (along the frontal crest and coronal suture), both parietals (along the sagittal sinus and coronal suture), both temporals (in the sigmoid sinus and on the roof of the auditory tube), the occipital (on the cruciform eminence, sagittal and transverse sinuses), and on the superior part of the lesser wings of the sphenoid. Similar new bone was also observed on the external surface of the skull (on the temporal bones), on the posterior surface of the right ilium (pelvis) and both tibial shafts (central and distal thirds of shins). A thin layer of white new bone was seen on the external occipital, the right mandibular body (around the mental foramen and the condyle), on the laminae of several thoracic and lumbar vertebrae, and on almost all ribs (along the costal groove).

Skeleton 50 (1-2 years) had deposits of raised grey woven bone in both orbits, but that on the left side was larger and more pronounced and there was some evidence of remodelling along the anterior part of the new bone. Both orbits also had a band of very fine porosity extending along the anterior margin of the orbit. Grey woven bone was present on the endocranial (inner) surfaces of the skull (Plate 2) on the parietals (beneath the bosses), in the right sigmoid sinus, and on the occipital (cruciform eminence, sagittal and transverse sinuses). Thin layers of new bone were also observed on the external surface of the skull, including the left greater wing of the sphenoid (right side lost post-mortem), the occipital (around the left condylar fossa), maxilla (right side more pronounced) (Plate 3), and mandible. There was a band of thickened, densely porous bone on the external surface of the skull on both parietals, along the mid-third of the lambdoid suture. Fine, scattered porosity was also observed on parts of the face: the left zygoma, on the left greater wing of the sphenoid, and the maxilla. Thin, white new bone was seen on the arches of several vertebrae, on the clavicles, the distal humeri, and both ilia (hips).

Plate 2 SK50, parietal with new bone formation on internal surface

Plate 3 Right maxilla with new bone formation and porosity

Skeleton 114 (5-6 years) also had new bone formation in both eye orbits: brown woven bone extending over a large portion of the surface and into the supraorbital notch on the right side, and along the anterior margin of the left side. There was diffuse, porous woven bone on other parts of the skull: over the glabellar region and supraorbital margins of the frontal bone, and endocranial new bone on the right parietal, and occipital (sagittal, transverse and sigmoid sinuses). There was bone similar in appearance to that in the orbits in both maxillary sinuses. Small patches of grey woven bone were noted on both clavicles, and on the right humerus, with more extensive new bone on both tibiae. Both tibiae also had an area of enlarged porosity on the posterior mid-shaft. Nine of the left ribs had an area of porous new bone on the internal surface at the sternal end of the shaft, extending up to 35mm from the sternal end (Plate 5). In two cases the bone was finely porous, five had 'capillary impressions' and porosity, and two showed some signs of remodelling. A further rib was missing the sternal end, but had a small patch of new bone on the internal superior border of the shaft. None of the eleven surviving right ribs were affected. The right radius had probably been fractured (see section 3.4).

Plate 4 Right orbit of SK 114 with new bone formation

Plate 5 Left ribs of SK 114 with porosity at sternal ends

In all three individuals some of the new bone may be related to normal growth, but that in the orbits is distinctly pathological, as is the new bone on the sternal ribs in Skeleton 114, and the porosity of the parietals (side parts of the skull) in Skeleton 50. Also, Ortner (2003, 390) has observed that the post-cranial lesions in archaeological skeletons are not as pronounced as those in clinical cases of scurvy. Both Skeletons 218 and

114 were small for their age (see section 2.3), indicating inhibited growth, which is no doubt linked to the poor health suffered by these individuals and could be a direct result of the scorbutic process.

Only one case of scurvy is described for the whole of prehistoric Britain (including the Iron Age) in Roberts and Cox (2003), so for three individuals to show possible signs of scurvy in such a small sample is somewhat unusual, giving an extremely high prevalence of 50% (overall) or 60% (of the non-adults). Skeleton 218 is of the age when infantile scurvy reaches its peak, at eight to ten months (Ortner 2003, 384), and Skeleton 50 is not much older. The two youngest individuals were too young for signs of scurvy to have manifested: it is rare before the age of four months unless the mother was also suffering from vitamin C deficiency during pregnancy (Ortner 2003, 384). The high prevalence of scurvy at Kirby Grindalythe suggests either that the population to which these children belonged was struggling to consume a diet adequate in vitamin C, possibly implying a lack of available fruits and vegetables, or that the food fed to these young children was nutritionally inadequate, possibly reflecting poor-quality weaning-foods.

3.2.2 Osteoporosis

Osteoporosis develops when bone mass is lost, making the bone less dense and more fragile. Bone mass is lost with increasing age by both sexes, but the change is more rapid in post-menopausal women. Bone mass can also be lost in response to pathological conditions, including endocrine disorders, malnutrition, and as a result of reduced mobility (Aufderheide and Rodríguez-Martín 1998; Ortner 2003). This loss of bone mass can lead to fractures, as the bone is no longer capable of withstanding normal biomechanical forces.

Plate 6 Two thoracic vertebrae of SK 138 with fractures and DJD

Osteoporosis was diagnosed in Skeleton 138 (mature adult male). The bones were extremely light, but more importantly the spine showed several characteristics typical of osteoporosis. There were compression fractures of several vertebral bodies, including thoracic vertebrae T4, T6, T7, T10, T11 and lumbar vertebra L5, and possibly also T5, T8 and L2 (Plate 6). This resulted in three wedge-shaped vertebrae and at least one 'cod-fish' vertebra. It is possible that some degree of kyphosis (forward bending of the spine) had occurred as a result. The bodies of two of the lumbar vertebrae had broken post-mortem, displaying the inner trabeculae (spongy bone), and it can be seen that vertical trabeculae predominate and the horizontal trabeculae are fewer and thinner. This is typical of the body's response to the loss of bone mass, with the weight-bearing vertical trabeculae kept over the non weight-bearing horizontal trabeculae (Aufderheide and Rodríguez-Martín 1998). No other fractures typical of osteoporosis were present. The osteoporosis of this individual might be associated with their age, but it should be considered that it is related to another pathological condition or syndrome. From the prominent muscle attachments it would seem that this person was leading an active life, so osteoporosis related to reduced mobility is not likely. Degenerative lesions were observed in the spine of this individual, discussed in section 3.3.

3.3 DEGENERATIVE JOINT DISEASE

The term joint disease encompasses a large number of conditions with different causes, which all affect the articular joints of the skeleton. Factors influencing joint disease include physical activity, occupation, workload and advancing age, which manifest as degenerative joint disease and osteoarthritis. Alternatively, joint changes may have inflammatory causes in the *spondyloarthropathies*, such as sceptic or rheumatoid arthritis. Different joint diseases affect the articular joints in a different way, and it is the type of lesion, together with the distribution of skeletal manifestations, which determines the diagnosis.

3.3.1 DJD

The most common type of joint disease observed tends to be degenerative joint disease (DJD). DJD is characterised by both bone formation (osteophytes) and bone resorption (porosity) at and around the articular surfaces of the joints, which can cause great discomfort and disability (Rogers 2001).

Skeleton 138 suffered from both spinal and extra-spinal DJD. Most of the thoracic (T4 and lower) and all surviving lumbar vertebral bodies had osteophytes around the margins (especially the anterior) and on the surface of the body (see Plate 6), interspersed with sharp-edged holes and smaller porosity. Degenerative changes were also visible in several apophyseal facets (joints between the vertebrae), mainly affecting the cervical (neck) and lumbar (lower back) vertebrae. These changes were probably linked to the osteoporosis and associated compression fractures of several vertebrae, which had certainly changed the normal relationship of the vertebrae to each other and altered the forces acting on the joints. They could also be the degenerative changes normally associated with advancing age.

Degenerative changes were seen in almost all the joints of Skeleton 138, most of which had osteophytes at the margins. However, additional porosity (and hence DJD) was only present in the medial and lateral clavicles (collar bones), glenoid fossae of the scapulae (shoulders) and the left acetabulum (hip). Slight porosity without osteophytes was also observed on the articular eminence of the glenoid fossa of the temporo-mandibular joint (jaw), although no changes were seen on either mandibular condyle.

3.3.2 Osteoarthritis

Osteoarthritis is a degenerative joint disease characterised by the deterioration of the joint cartilage, leading to exposure of the underlying bony joint surface. The resulting bone to bone contact can produce polishing of the bone termed 'eburnation', which is the most apparent expression of osteoarthritis. Osteoarthritis can be the result of mechanical stress and other factors, including lifestyle, food acquisition and preparation, social status, sex and general health (Larsen 1997, 179).

Skeleton 138 also suffered from spinal osteoarthritis in the form of eburnation, osteophytes and porosity in two of the vertebral apophyseal joints: the left joint between cervical vertebrae C3 and C4 (neck), and the right joint between L5 and S1 (where the spine meets the pelvis). In addition one of the joints in the fingers (the inter-phalangeal joint between the intermediate and distal phalanges of the second or third digit in the right hand) had osteoarthritis in the form of eburnation and osteophytes. These changes may be age- or activity-related, but those in the spine could be linked to the osteoporosis.

3.3.3 Schmorl's Nodes

A different condition which affects the spine is Schmorl's nodes. Schmorl's nodes are indentations in the upper and lower surfaces of the vertebral bodies, most commonly in the lower thoracic vertebrae (Hilton *et al.* 1976). Schmorl's nodes can result from damage to the intervertebral discs, which then impinge onto the vertebral body surface (Rogers 2001), and may cause necrosis (death) of the surrounding tissue. Rupture of the discs only occurs if sufficient axial compressive forces are causing pressure on the central part of the discs; frequent lifting or carrying of heavy loads can cause this. Schmorl's nodes were observed in the lower thoracic and upper lumbar spine of Skeleton 138.

3.4 TRAUMA

Skeleton 114 (5-6 years old) had a possible fracture of the right radius (Plate 7). The right bone was 2mm shorter than the left radius, the central and proximal third of the shaft were swollen and thickened, and the proximal end was angled more distally in comparison to the left side. The posterior medial third is covered in fine porous, partially remodelled woven bone. Alternatively, these changes could represent osteitis (bone infection), or be related to the other changes associated with scurvy described in section 3.2.

Plate 7 Radii of SK 114, with a fracture of the right radius

Several compression fractures were observed in the vertebrae of Skeleton 138, described in section 3.2.2, and are believed to result from osteoporosis (see Plate 6).

Occasionally, it is possible to infer trauma to the soft tissue on the bones, in the form of ligamentous or muscular trauma. This is expressed through the formation of bony processes (*enthesopathies*) at the site of ligament attachments. Additionally, it is possible to observe bone defects at the site of muscle insertions, which are the result of constant micro-trauma and are usually activity-related (Hawkey and Merbs 1995, 334).

The bones of Skeleton 138 (mature adult male) were robust, with well-developed muscle attachment sites, particularly: those on the clavicle and humerus for the *deltoid* muscle, which abducts, flexes, extends and rotates the arm; the greater tubercular crest, where *pectoralis major* and *latissimus dorsi* attach, both of which adduct and medially rotate the arm; the attachment site for *pronator teres* on the radius, which pronates and helps to flex the forearm; the *supinator crest* of the ulna, for the *supinator* muscle which supinates the forearm; the gluteal line where *gluteus maximus* attaches, and the posterior iliac crest where *gluteus medius* attaches, both involved in abduction and rotation of the thigh with *gluteus maximus* also responsible for extending the thigh and trunk; and the soleal line on the tibia where *soleus* attaches, which plantar flexes the foot (pushes the foot downwards) (Stone and Stone 1990). These well-developed muscle attachment sites suggest a life of activity, involving walking, and use of the arms. Signs of trauma to the *sartorius* muscle, which runs from the hip to below the knee and is involved in flexion, abduction and rotation of the thigh, were observed in the form of marked projections of bone (*enthesopathies*) in the area between the anterior superior and inferior iliac spines on the left ilium (pelvis), and irregular, porous bone on the adjacent posterior surface of the ilium.

3.5 NEOPLASTIC DISEASE

A button, or ivory, osteoma was observed on the right parietal bone of Skeleton 138. These are the most common type of neoplasm (new growth) seen in archaeological populations, usually affect males more than females, and are entirely benign and symptomless **(Aufderheide and Rodríguez-Martín 1998).**

3.6 MISCELLANEOUS

Skeleton 138 exhibited an unusual collection of lesions that may possibly be related to a congenital syndrome or an endocrine disorder. The osteoporosis and degenerative changes have already been discussed above, and the disproportionately short lower legs described in section 2.5. In addition, the shaft of the fourth left metacarpal (one of the bones in the palm of the hand) was thin in comparison to the right side and to the other left metacarpals, although both proximal and distal ends (joints) appeared normal in size.

The internal cranial vault was thickened and covered with irregular, rounded nodules of bone, which were especially pronounced on the anterior frontal, either side of the frontal crest. They continued along the sagittal sinus (parietals) onto the transverse and sigmoid sinuses (occipital and temporals); they extended over the whole of the inner temporal bones and the sphenoid, which appeared to have arachnoid granulations on the greater wing. Arachnoid granulations are depressions of unknown cause, which tend to be seen in post-menopausal females.

Much of the internal frontal bone is ridged and wrinkled in appearance; these radiate on the frontal crest. The meningeal grooves running parallel to the coronal suture are extremely deep. One possibility is that this man suffered from hyperostosis frontalis interna (HFI), although these lesions are usually restricted to the frontal bone and rarely the parietal and temporal bones; no mention is made of the involvement of the sphenoid and occipital in the palaeopathological literature (Ortner **2003; Aufderheide and Rodríguez-Martín 1998).** In addition these lesions are usually found in women over 30, although they can occur in males. The difficulty in determining the sex of this individual has already been discussed; if this is HFI, then the likelihood that this individual was female increases. Finally, the inferior surface of the petrous temporal bones (at the base of the skull) was covered with diffuse small holes with rounded edges. Porosity also extended around the foramen magnum and on the basilar process, although this area had been damaged post-mortem.

3.7 CONCLUSION

Three of the children present had skeletal changes that could possibly be attributed to scurvy, a disease rarely reported in archaeological human remains. Only one other case in prehistoric Britain has been described, so the occurrence of three individuals at the same site is particularly noteworthy. One of these individuals had also suffered a broken arm, and two had experienced inhibited growth, which could possibly be linked to the scorbutic changes. It is clear that these children had suffered from malnutrition, consuming a diet lacking in vitamin C from fresh fruits and vegetables. This could reflect the food available to the population in general, perhaps indicating a period of famine, or it could reflect the cultural practices governing the feeding of infants, or circumstances concerning these infants in particular.

The adult skeleton demonstrated a variety of pathological lesions, including osteoporosis which had led to fractures of the spine, and degenerative joint disease and osteoarthritis in several joints. The latter was possibly related to the individual's mature age, but the evidence for activity in the form of developed muscle attachments, suggests the degenerative changes could in part be related to activity. The degeneration of the spine was probably largely associated with osteoporosis. Unusual features recorded include the short lower legs, the small metacarpal (hand bone), and the presence of extensive bony nodules inside the skull. These features (including the osteoporosis) could all be characteristics of an endocrine or congenital disorder, although further research would have to be carried out into this possibility.

4.0 DENTAL HEALTH

Analysis of the teeth from archaeological populations provides vital clues about health, diet and oral hygiene, as well as information about environmental and congenital conditions. Five of the six skeletons had teeth or tooth positions surviving for observation, although none of the teeth of Skeletons 218 and 3007 had erupted, and most were only partially formed. Of the 107 tooth positions present, 75 belonged to non-adults and 32 to the adult skeleton. Of the 54 deciduous (milk) teeth present only 28 had actually erupted (see Table 3). Seventy-two permanent teeth were present among the non-adult skeletons, none of which had erupted. The only erupted permanent teeth were the six teeth belonging to Skeleton 138. Therefore, the total number of erupted teeth was 34 (6 permanent, 28 deciduous).

Table 3 Summary of dental pathology

Skeleton No	Number of teeth present	Calculus	Caries	Abscesses	DEH	Infractions	Wear	Periodontitis
50	17 deciduous (11 erupted, 6 unerupted/ erupting) 5 permanent (unerupted)	3	0	0	1	-	Absent to slight	-
114	17 deciduous (erupted) 9 permanent (4 erupting, 5 unerupted)	0	1	0	0	-	Slight	-
138	6 permanent	6	0	1	0	-	Mixed: slight to severe	Considerable
218	12 deciduous (unerupted) 4 permanent (unerupted)	-	-	-	-	-	-	-
3007	8 deciduous (unerupted)	-	-	-	-	-	-	-

Twenty-six of the permanent teeth from Skeleton 138 had been lost ante-mortem (81.3% of the permanent tooth

Plate 8 Mandible of SK138 with last remaining tooth

positions), and the mandible was practically edentulous, with only one surviving canine (Plate 8). The causes of ante-mortem tooth loss (the loss of teeth during life) include dental caries (tooth decay), heavy wear of the teeth exposing the pulp, and periodontal disease. Once the tooth has been lost, the empty socket is filled in with bone.

Dental wear tends to be more common and severe in archaeological populations than in modern teeth. Severity of the dental wear was assessed using a chart developed by Smith (1984): each tooth was scored using a grading system ranging from 1 (no wear) to 8 (severe attrition of the whole tooth crown). The wear of the surviving teeth in Skeleton 138 was extremely variable, with the left upper and lower canines being worn down to the roots, but the right upper premolars were only slightly worn and their occlusal surfaces were partially covered with calculus (mineralised plaque deposits). This suggests the lower right premolars were lost early, preventing further wear of their opposing teeth. Calculus is commonly observed in archaeological populations whose dental hygiene was not as rigorous as it is today: calculus mineralises and forms concretions on the tooth crowns, along the line of the gums. Slight calculus was present on all six surviving teeth in Skeleton 138. None of the teeth of Skeleton 138 had dental caries, but there was an abscess cavity beneath the root of the surviving lower left canine. Dental abscesses occur when bacteria enter the pulp cavity of a tooth causing inflammation and a build-up of pus at the apex of the root. Eventually, a hole forms in the surrounding bone allowing the pus to drain out and relieve the pressure. They can form as a result of dental caries, heavy wear of the teeth, damage to the teeth, or periodontal disease (Roberts and Manchester 1995), and heavy tooth wear seems to be the likely cause here.

None of the teeth of Skeletons 218 and 3007 had erupted, and most were only partially formed, so they could not be considered for the presence of most dental diseases. Therefore, only two of the non-adults had erupted dentitions. Three (10.7%) of the deciduous teeth from Skeleton 50 had tiny flecks of calculus on the mesial surfaces. One tooth (a lower first deciduous molar) had a small carious lesion on the occlusal surface, in a fissure, giving a prevalence of 3.6%. Dental caries (tooth decay) forms when bacteria in the plaque metabolise sugars in the diet and produce acid, which then causes the loss of minerals from the teeth and eventually leads to the formation of a cavity (Zero 1999). It is uncommon in early archaeological populations due to the lack of refined sugars in the diet, but undernutrition can predispose to caries development (Moynihan 2003). Dental wear in both individuals was absent to slight, reflecting their young age. Dental enamel hypoplasia (DEH) was only observed in one tooth of Skeleton 50: there was a pit on the distolingual cusp of the upper right first permanent molar. DEH is the manifestation of lines, grooves or pits on the crown surface of the teeth, which represent the cessation of crown formation. The defects are caused by periods of severe stress during the first to seventh year of childhood, including malnutrition or disease.

5.0 MORTUARY PRACTICE

Skeleton 138 (mature adult male) was lying on its left side, with the legs flexed at the hips and knees, the left hand between the knees and the right hand underneath the head, and the head to the south-west. The right arm